Missouri Department of Transportation

Bridge Division

Bridge Design Manual

Section 3.76

Revised 07/10/2002

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3.76.1 Design

3.76.2 Dimensions

3.76.3 Reinforcement

3.76.4 Details

DESIGN UNIT STRESSES (also see Section 4 - Note A1.1)

(1) Reinforced Concrete

Class B Concrete (Substructure) fc = 1,200 psi f'c = 3,000 psi

Reinforcing Steel (Grade 60) fs = 24,000 psi fy = 60,000 psi

n = 10

$Ec = W^{1.5} \times 33 \sqrt{f'c}$ (AASHTO Article 8.7.1) (✳)

(2) Structural Steel

Structural Carbon Steel (ASTM A709 Grade 36)
fs = 20,000 psi fy = 36,000 psi

(3) Piling

For pile capacity, see Bridge. Manual Sec. 1.4 and 3.74.

(4) Overstress

The allowable overstresses as specified in AASHTO Article 3.22 shall be used where applicable for Service Loads design method.

(✳) $Ec = 57{,}000 \sqrt{f'c}$ for W = 145 pcf., $Ec = 60{,}625 \sqrt{f'c}$ for W = 150 pcf.

LOADS

(1) Dead Loads

As specified in Bridge Manual Section 1.2.

(2) Live Load

As specified on the Design Layout.
Impact of 30% is to be used for design of the beam. No impact is to be used for design of any other portion of bent including the piles.

(3) Temperature, Wind and Frictional Loads

Wind and temperature forces can be calculated based on longitudinal force distribution as described in Bridge Manual Section 1.2.4.3.2.

DISTRIBUTION OF LOADS

(1) Dead Loads

Loads from stringers, girders, etc. shall be concentrated loads applied at the intersection of centerline of stringer and centerline of bearing.

(2) Live Load

Loads from stringers, girders, etc. shall be applied as concentrated loads at the intersection of centerline of stringer and centerline of bearing.

(3) Temperture

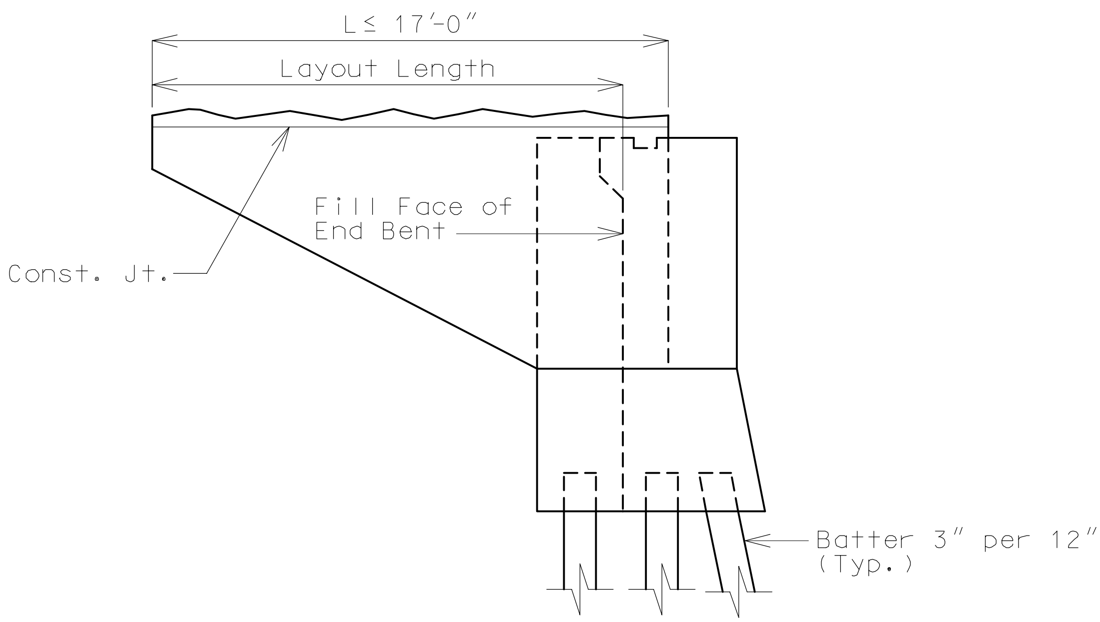
The force due to expansion or contraction applied at bearing pads are not used for stability or pile bearing computations. However, the movement due to temperature should be considered in the bearing pad design and expansion device design.

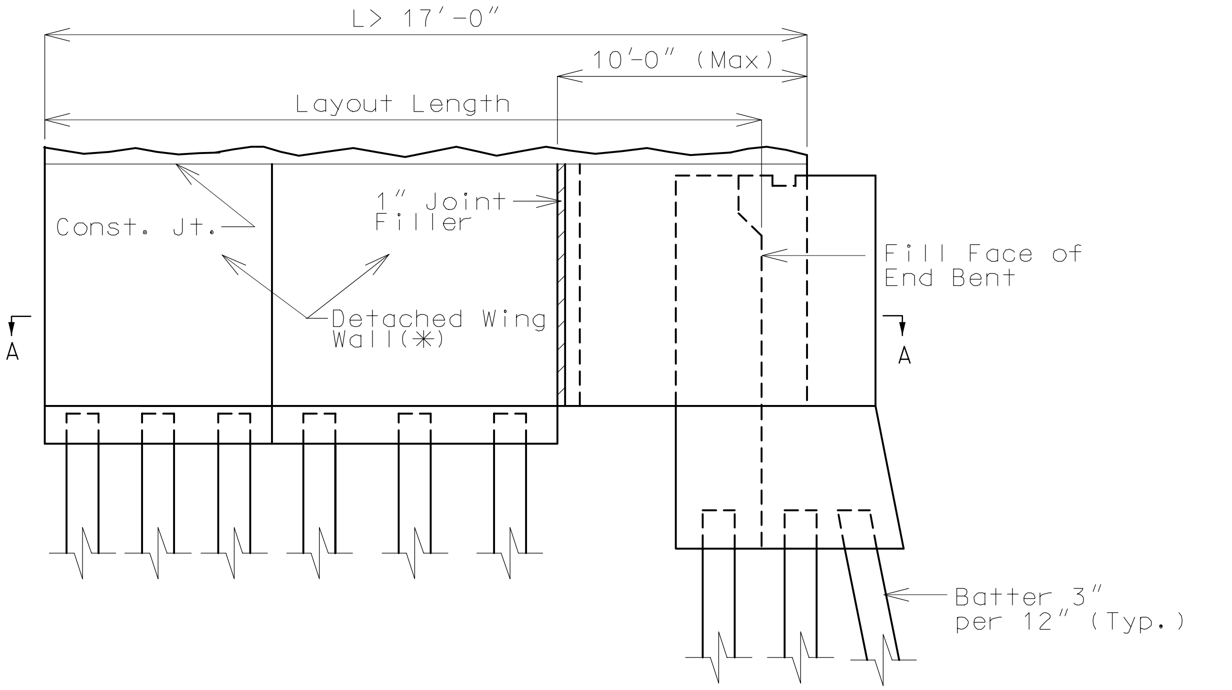
DISTRIBUTION OF LOADS (CONT.)

(4) Wing with Detached Wing Wall

When Wing Length, L, is greater than 17'-0", use maximum of 10'-0" rectangular wing wall combined with a detached wing wall.

When detached wing walls are used, no portion of the bridge live load shall be assumed distributed to the detached wing walls. Design detached wing wall as a retaining wall, see Sec. 3.62 for retaining wall design. (The weight of Safety Barrier Curb on top of the wall shall be included in Dead Load.)



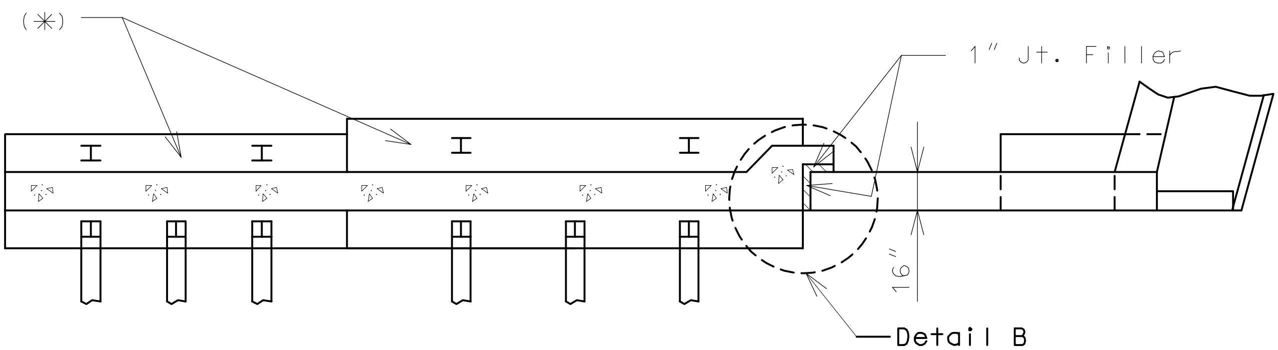


(✳) Detached wing wall shown is for illustration purpose only. Design detached wing wall as a retaining wall, see Section 3.62 of this manual.

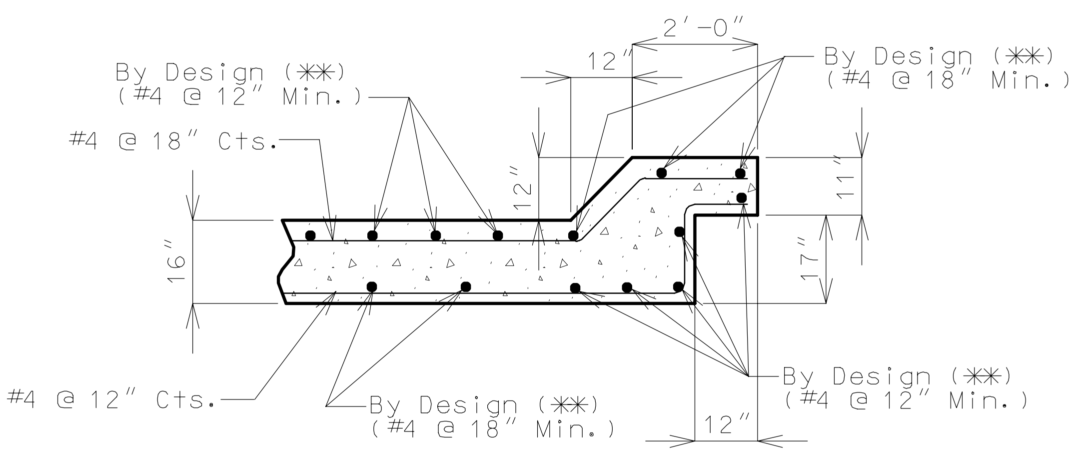
For details of Section A-A, see page 1.1-3 of this section.

DISTRIBUTION OF LOADS (CONT.)

(4) Wing with Detached Wing Wall (Cont.)



SECTION A-A



DETAIL B

(✳) Detached wing wall shown is for illustration purpose only. Design detached wing wall as a retaining wall, see Section 3.62 of this manual.

(✳✳) See retaining wall design.

For location of Section A-A, see page 1.1-2 of this section.

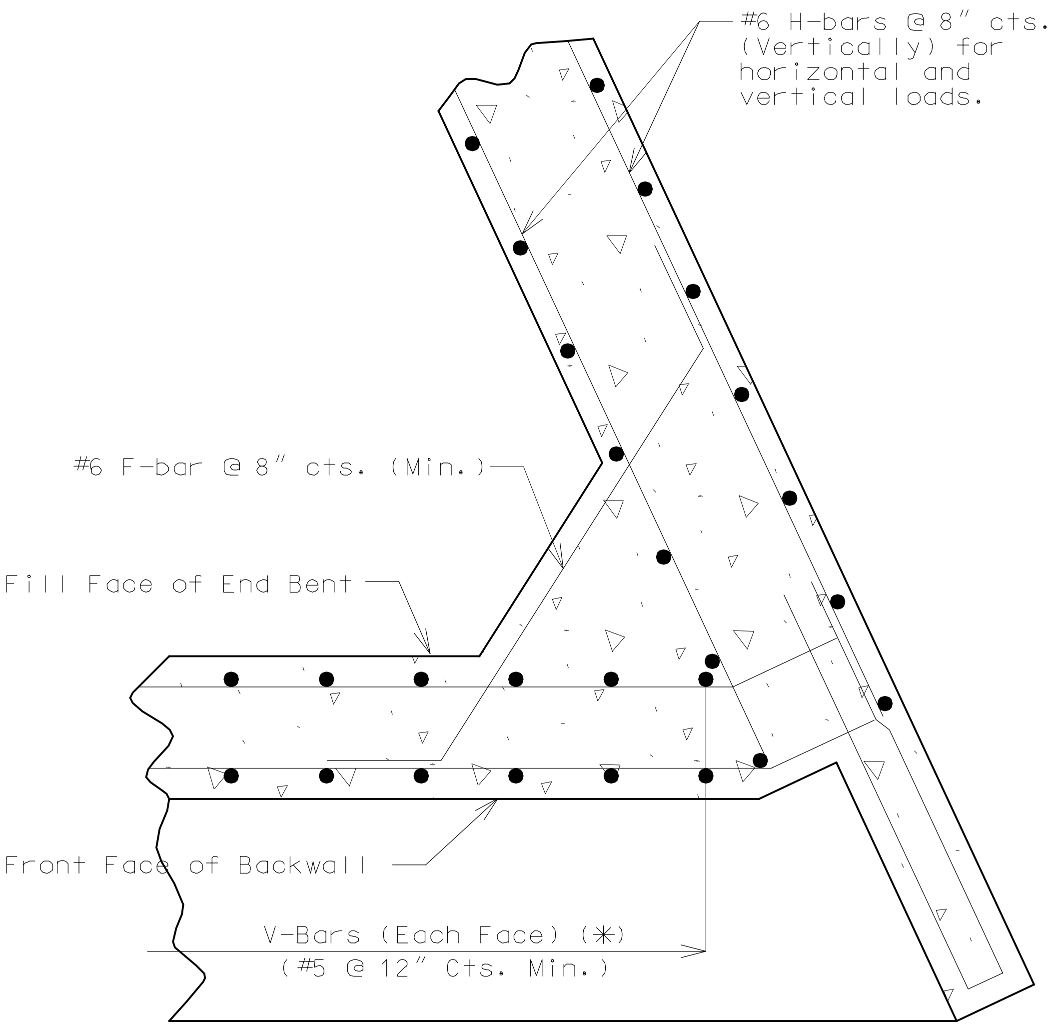
DESIGN ASSUMPTIONS - LOADINGS

(1) Beam

The beam shall be assumed continuous over supports at centerline of piles. One half of the dead load of the approach slab shall be included in the beam design.

(2) Wing and Backwall(See Example 1)

(a) Vertical Loads
The minimum steel placed horizontally in wings shall be #6 bars at 8" centers, each face. These bars should be adequate to support the wing. See figure below.



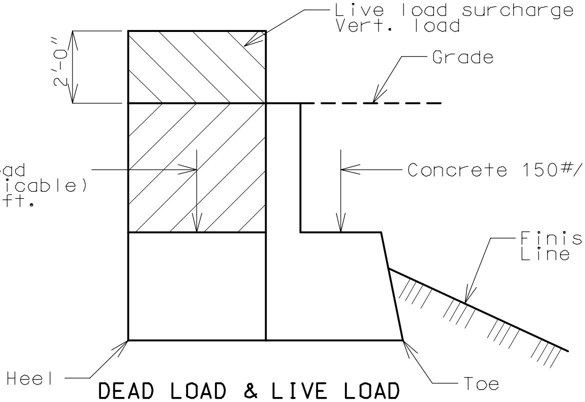
PART SECTION THRU BACKWALL AND WING

(✳) See page 3.1-7 of this Section for V-bar size and spacing.

DESIGN ASSUMPTIONS - LOADINGS (CONT.)

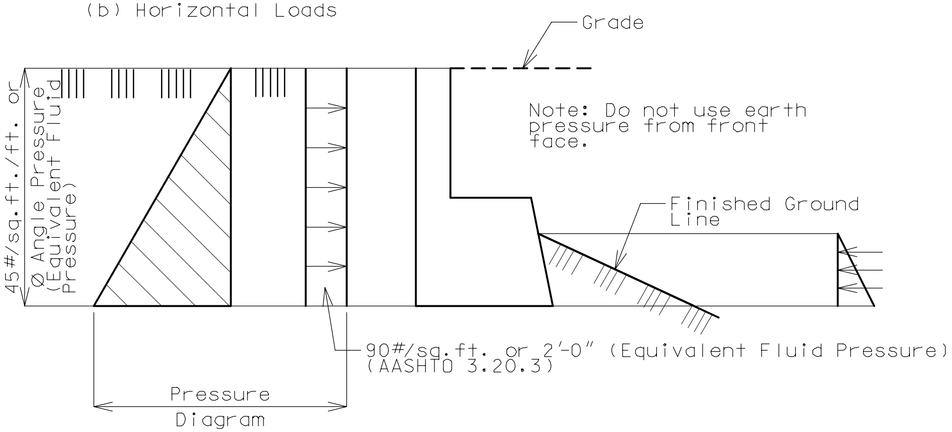
(2) Wing and Backwall (Cont.)

(a) Vertical Loads (Cont.)

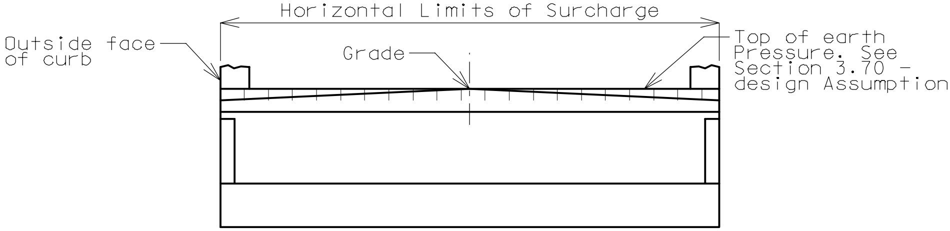


DEAD LOAD & LIVE LOAD

(b) Horizontal Loads



EQUIVALENT FLUID PRESSURE AND LIVE LOAD SURCHARGE



LIMITS OF EARTH PRESSURE AND SURCHARGE

Note: The minimum steel (horizontally) in the corner haunch at the junction of the wing and backwall shall be #6 bars at 8" cts. " ", see page 1.2-1 of this section.

DESIGN ASSUMPTIONS – LOADINGS (CONT.)

3) Piles

a. Stresses in the piles due to bending need not be considered in design calculations except for seismic design in categories B, C, and D.

b. The following four loading cases should be considered.

Case	Vertical Loads	Horizontal Loads	Special Consideration
I	DL + E + SUR	EP + SUR	-
II	DL + LL + E + SUR	EP + SUR	-
III	DL + LL + E	EP	-
IV	DL + LL + E	None	Allow 25% Overstress

Where,
LL = live load
DL = dead load of superstructure, substructure and one half of the approach slab
SUR = two feet of live load surcharge
E = dead load of earth fill
EP = equivalent fluid pressure of earth
Maximum pile pressure = pile capacity
Minimum pile pressure = 0 (tension on a pile will not be allowed for any combination of forces except as noted)

4) Analysis Procedure

a. *Find the lateral stiffness of a pile, K_δ:*
With fixed pile-head (i.e., only translation movement is allowed but no rotation allowed): The lateral stiffness of a pile can be estimated using Figures 1 and 3 or 2 and 3 for pile in cohesionless or cohesive soil, respectively. The method of using Figures 1, 2, and 3 to find lateral stiffness is called Linear Subgrade Modulus Method. Usually the significant soil-pile interaction zone for pile subjected to lateral movement is confined to a depth at the upper 5 to 10 pile diameters. Therefore, simplified single layer stiffness chart shown in Figure 3 is appropriate for lateral loading. The coefficient f in Figures 1 and 2 is used to define the subgrade modulus E_s at depth "z" representing the soil stiffness per unit pile length. For the purpose of selecting an appropriate f value, the soil condition at the upper 5 pile diameters should be used. Since soil property, friction angle ϕ, or cohesion c, is needed when Figure 1 or 2 is used, determine soil properties based on available soil boring data. If soil boring data is not available, one can conservatively use f value of 0.1 in Figure 3. Designer may also use soil properties from Table 6.1.2.4.2 in Bridge Manual Section 6.1 to convert SPT N value to friction angle ϕ, or cohesion c, for granular or cohesive soil, respectively. Figures 1 and 2 were based on test data for smaller-diameter (12 inches) piles, but can be used for piles up to about 24 inches in diameter. In Figure 2, the solid line (by Lam et al. 1991) shall be used in design.

b. *Find the axial stiffness of a pile, K_a:*

For friction pile, K_a may be determined based on a secant stiffness approach as described in Bridge Manual Section 6.1 – Seismic Design or by the in-house computer program "SPREAD" where K_a is calculated as:

$$\frac{1}{K_a} = \frac{1}{AE/L'} + \frac{1}{K_{Q_f}} + \frac{1}{K_{Q_b}} \qquad \text{Equation (1)}$$

Where:
A = cross sectional area of pile
E = elastic modulus of pile
L' = total length of pile
K_{Qf} = secant stiffness due to ultimate friction capacity of the pile as described in Bridge Manual Section 6.1
K_{Qb} = secant stiffness due to ultimate bearing capacity of the pile as described in Bridge Manual Section 6.1

For HP bearing pile on rock K_a shall be calculated as:

$$\frac{1}{K_a} = \frac{1}{AE/L'} + \frac{1}{K_{Q_f}} \qquad \text{Equation (2)}$$

Or Conservatively, K_a may be determined as:

$$K_a = \frac{AE}{L'} \qquad \text{Equation (3)}$$

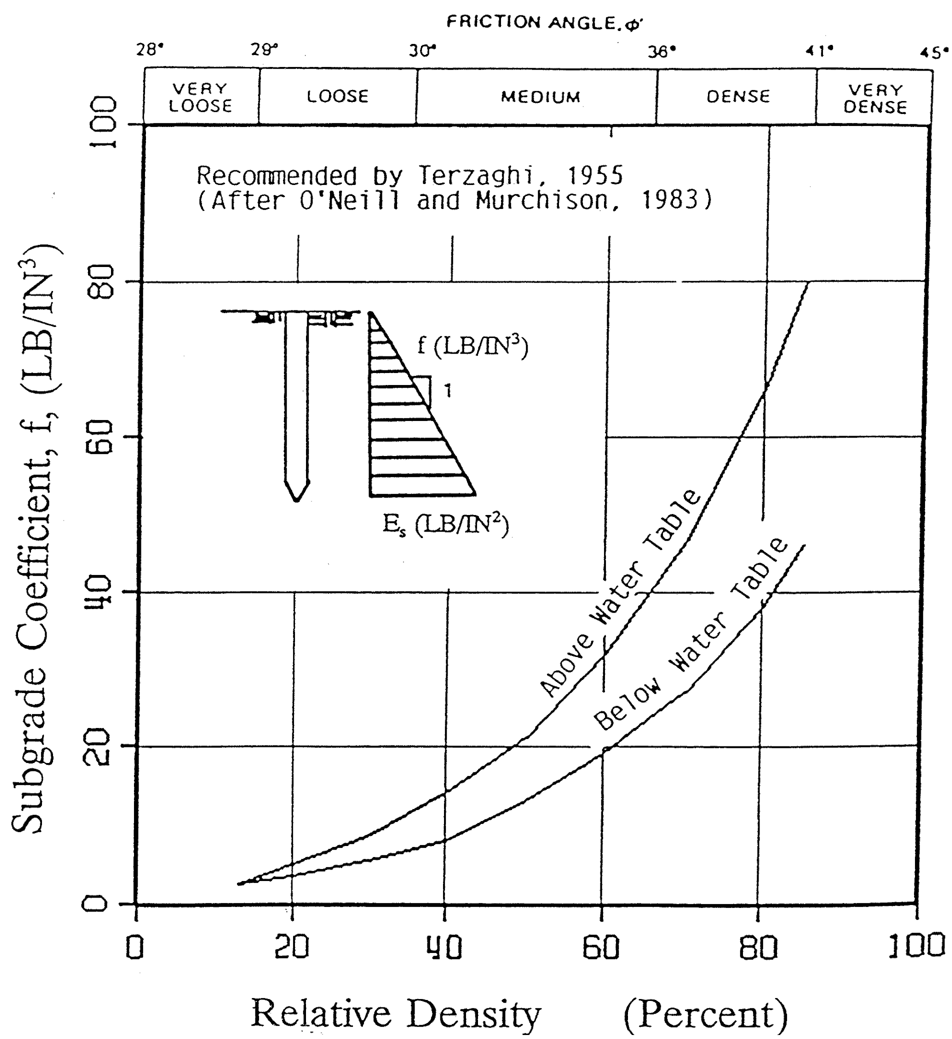


Figure 1. Recommended Coefficient f of Variation in Subgrade Modulus with Depth for Sand

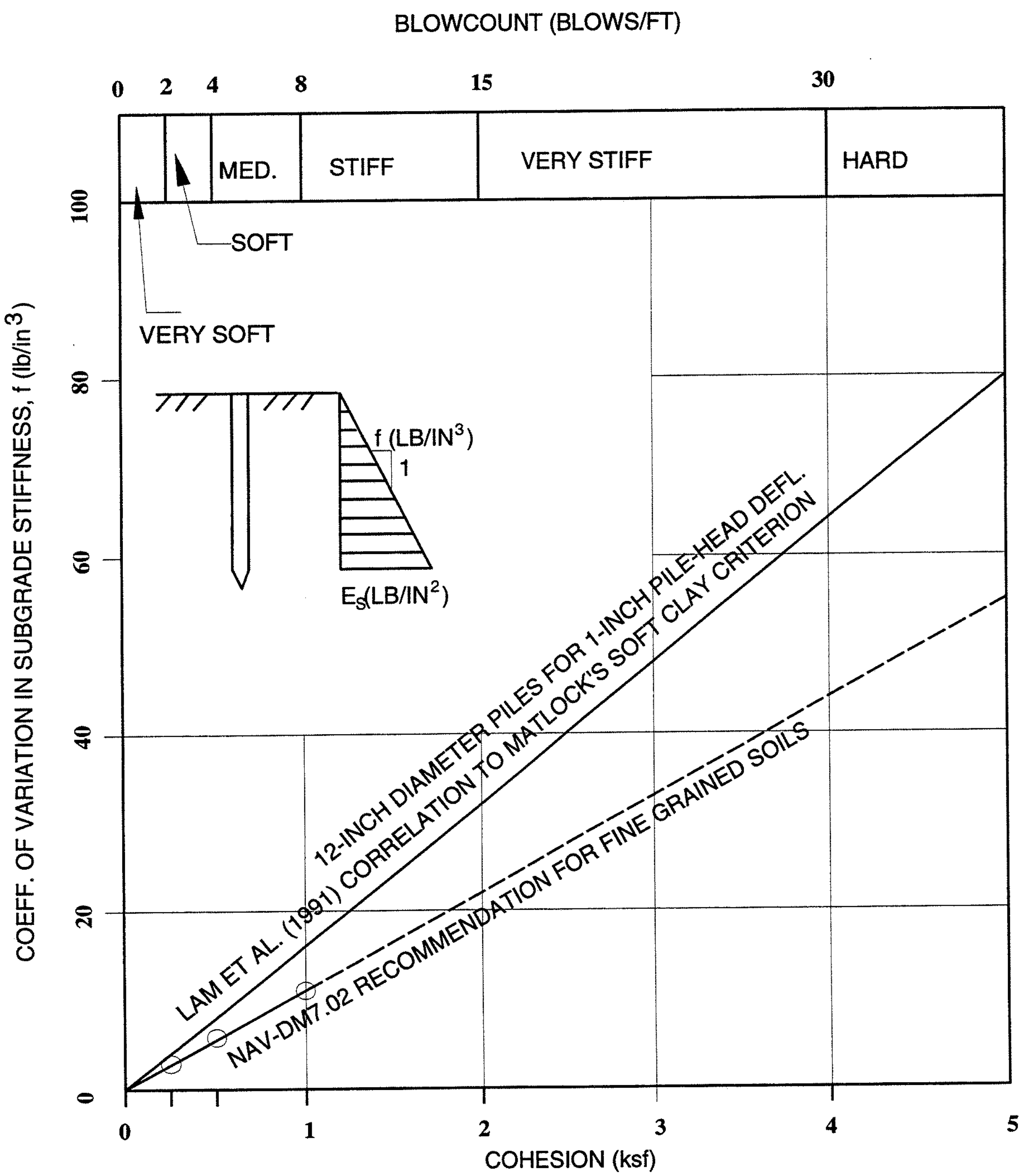
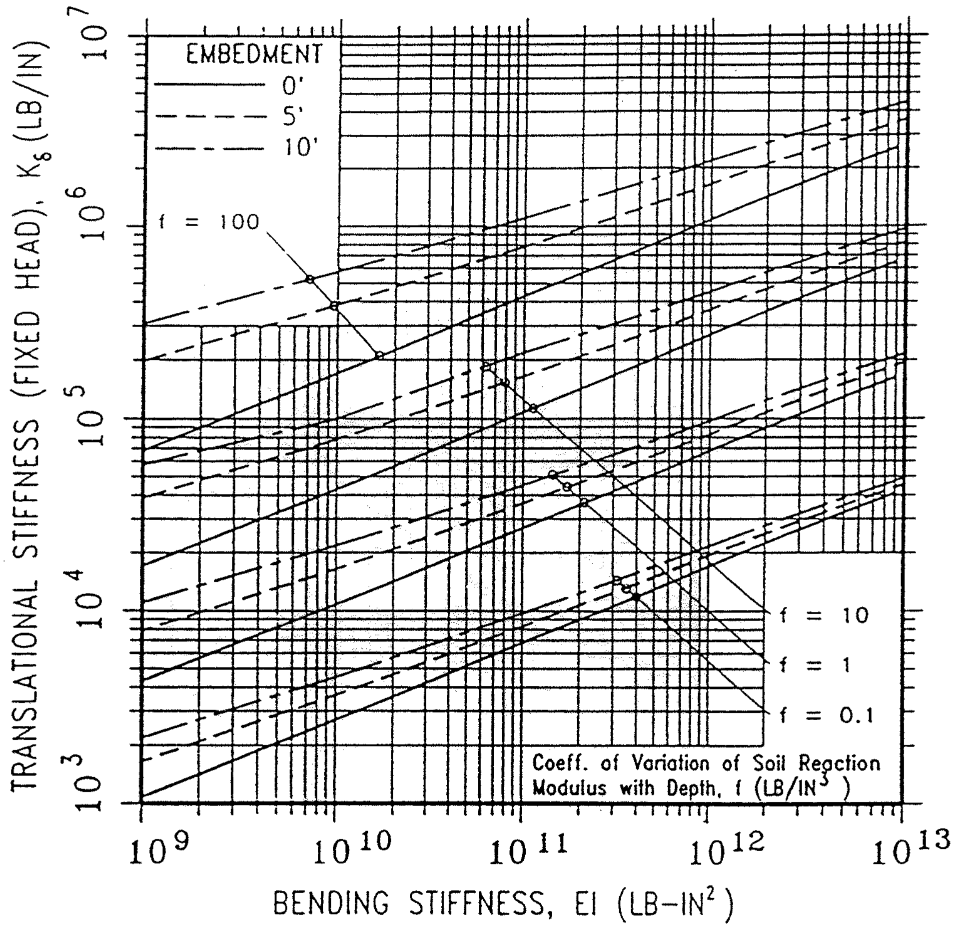


Figure 2. Recommended Coefficient f of Variation in Subgrade Modulus with Depth for Clay



$$P_t = K_\delta \cdot \delta + K_{\delta\theta} \cdot \theta$$

$$M_t = K_{\delta\theta} \cdot \delta + K_\theta \cdot \theta$$

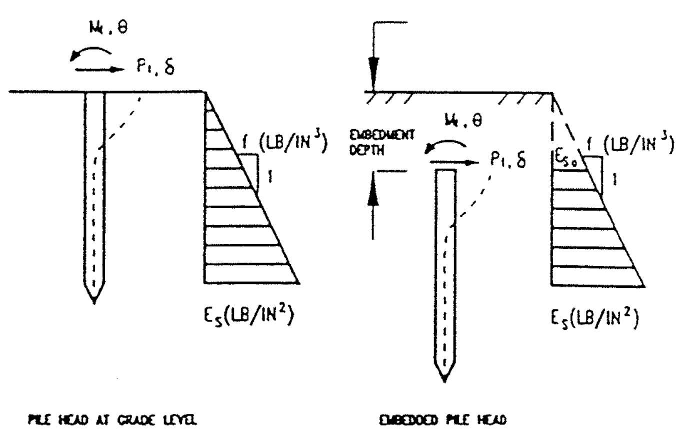


Figure 3. Lateral Embedded Pile-Head Stiffness

c. *Find the equivalent cantilever pile length, L*
For the structural model used in the structural analyses of loading cases I through IV. As shown in Figure 4, length L can be calculated as:

$$L = \left(\frac{12EI}{K_\delta} \right)^{1/3} \qquad \text{Equation (4)}$$

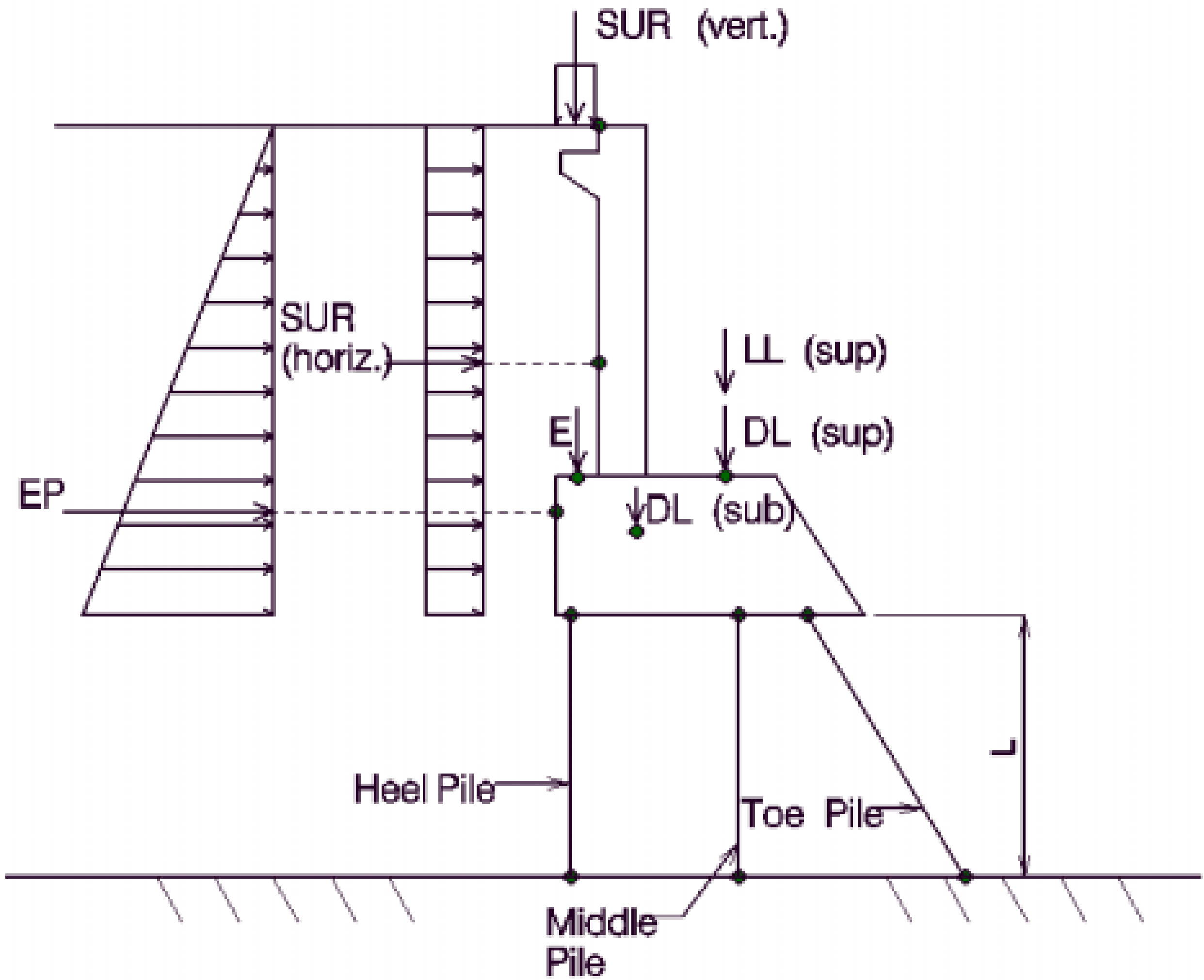


Figure 4. Structural Model

d. Find the equivalent pile area, A_e:
Once the equivalent cantilever pile length has been determined from step (c) above, the equivalent axial rigidity of the pile, $A_e * E_e$, can be calculated as $A_e * E = K_a L$. Then, the equivalent pile area, A_e, is equal to

$$A_e = \frac{K_a L}{E} \qquad \text{Equation (5)}$$

e. Perform structural analyses for loading cases I through IV.
Use computer programs STRUCT3D, SAP2000 or any other program capable of running static analysis.

f. Check abutment movement at the top of backwall and at the bottom of beam cap.

Maximum movement away from the backfill shall not be greater than 1/8”. Maximum movement toward the backfill shall not be greater than ¼”.

g. *Check pile axial loads from the analysis with the allowable pile axial load capacity described in Bridge Manual 3.74.*

h. *Check overturning of bent.*
Conservatively, use the same equivalent cantilever pile length, L. Check overturning of bent at the bottom of toe pile for loading cases I and II (Figure 4).

Case I	Point of Investigation	Vertical Loads (*)	Horizontal Loads	Factor of Safety (**)
I	Toe Pile	DL + E	EP + SUR	1.2
II	Toe Pile	DL + LL + E	EP + SUR	1.5

* Factor of safety is the ratio of resisting moment to overturning moment. Do not include pile reactions when calculating resisting and overturning moments.
** Neglect vertical surcharge and approach slab dead load for overturning check.

5) Deadman Anchorage System

Deadman anchorage can be used when the abutment movement exceeds the allowable movement.

The size and location of deadman anchorage shall be designed appropriately to maintain the stability of the abutment.

The deadman forces may be used to resist overturning with the approval of the Structural Project Manager.

6) Passive Pressure Shear Key (if applicable)

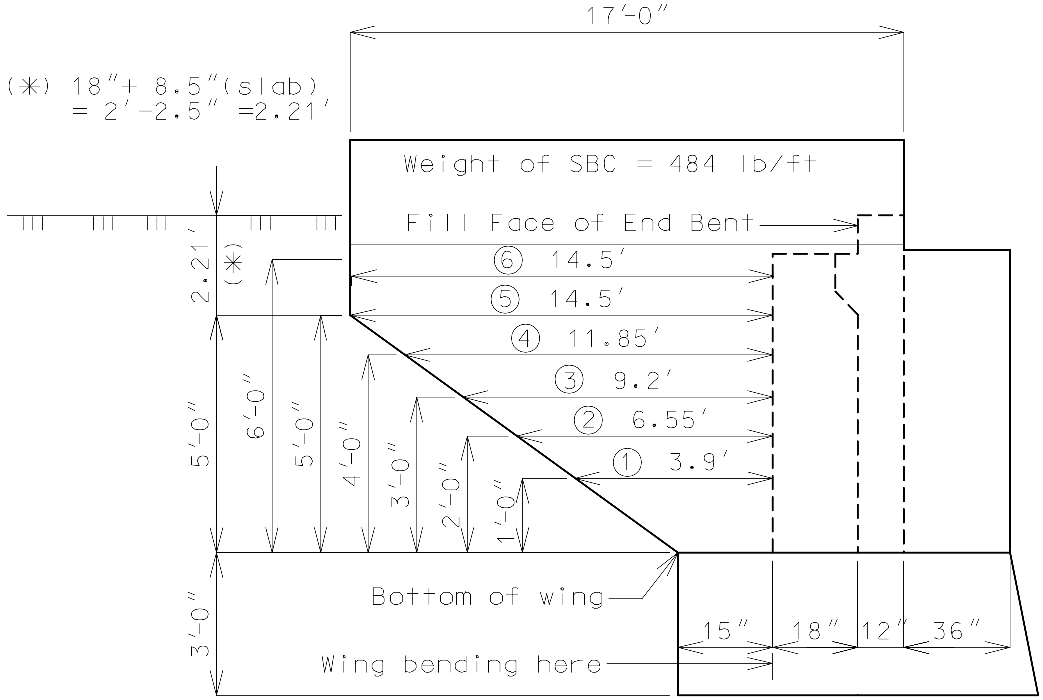
Passive pressure shear key may be used when the abutment movement exceeds the allowable movement.

The passive resistance of soil to the lateral force at shear keys may be used with the approval of structural project manager. See examples in Bridge Manual Section 3.62.3 for detail calculation.

DESIGN EXAMPLES

Example 1:

Design horizontal reinforcement of the following wing with wing length of 17'-0". Use 90 psf for live load surcharge and 45 psf/linear foot for earth pressure. (Use Load Factor Design)



Solve:

Factored Soil Pressure = 1.3 8 x45 psf/ft =1.3x1.3x45 psf/ft = 76.05 psf/ft.
Factored Surcharge = 1.3 8 x90 psf = 152.1 psf (AASHTO 5.14.1, 5.14.2)

a) Find the bending of wing of wing about edge of corner haunch due to earth pressure and live load surcharge:

1st Foot from bottom of wing (h=6.21')

EP = Earth Pressure = Soil Pressure + Surcharge
EP = (6.21'x76.05 psf/ft) + 152.1 psf = 624.37 psf
M = Moment = (624.37 psf)(3.9'x1')(3.9'/2) = 4,824 ft.-lb

2nd Foot from bottom of wing (h=5.21')

EP = (5.21'x76.05 psf/ft) + 152.1 psf = 548.32 psf
M = (548.32 psf)(6.55'x1')(6.55'/2) = 11,762 ft.-lb

3rd Foot from bottom of wing (h=4.21')

EP = (4.21'x76.05 psf/ft) + 152.1 psf = 472.27 psf
M = (472.27 psf)(9.2'x1')(9.2'/2) = 19,987 ft.-lb

4th Foot from bottom of wing (h=3.21')

EP = (3.21'x76.05 psf/ft) + 152.1 psf = 396.22 psf
M = (396.22 psf)(11.85'x1')(11.85'/2) = 27,819 ft.-lb

DESIGN EXAMPLES (CONT.)

Example 1(Cont.)

5th Foot from bottom of wing (h=2.21′)
EP = (2.21′x76.05 psf/ft) + 152.1 psf = 320.17 psf
M = (320.17psf)(14.5′x1′)(14.5′/2)= 33,658 ft-lb

6th Foot from bottom of wing (h=1.21′)
EP = (1.21′x76.05 psf/ft) + 152.1 psf = 244.12 psf
M = (244.12 psf)(14.5′x1′)(14.5′/2) = 25,663 ft-lb

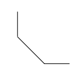
Mu=33,658 ft-lb, f′c= 3 ksi, fy= 60 ksi, Ø = 0.9,
Assume #6 vert. bar, #6 hori. bar, h=wing wall thickness= 16″, b = 12″
Effective d =16″-2″clear(exposed to earth)-0.75″(vert.bar)-0.375″(hori.bar)
d =12.875″

$$As = \frac{0.85 f'c\, bd}{fy}\left[1-\sqrt{1-\frac{2\ Mu\ (12''/ft)}{0.85\ f'c\ \varnothing\ bd^2}}\ \right]$$

$$As = \frac{(0.85)(3\ ksi)(12'')(12.875'')}{(60\ ksi)}\left[1-\sqrt{1-\frac{(2)(33.658\ kip\text{-}ft)(12''/ft)}{(0.85)(3\ ksi)(0.9)(12'')(12.875'')^2}}\ \right]$$

As(required)= 0.609 in^2

$$As(min.) = \frac{(1.7)(h^2)b\sqrt{fc'}}{d\ fy} = \frac{(1.7)(16'')^2(12'')\sqrt{3000}}{(12.875'')(60000)} = 0.370\ in^2 < 0.609\ in^2$$

$\boxed{\text{Use \#6 bars @ 8''}}$ For wing horizontal bars and  bar at corner haunch.

As(provided)= 0.663 in^2>0.609 in^2(required), O.K.

b)Find the bending of wing due to vertical dead load:

Barrier curb weight = 0.484 kip/ft

Factor load moment at corner haunch

Mu = 1.3{(0.484 kip/ft x14.5′x14.5′/2) + (0.15 kip/cf)(1.33′)

(1.5′x14.5′x14.5′/2+0.5x13.25′x5′x(13.25′/3+1.25′)+5′x1.25′x1.25′/2)}

Mu = 1.3{50.88 + 31.53 + 37.54 + 0.78} = 156.9 ft-kip

Assume use #6 bar for bending, b = 16″, h =78″,
Efifctive d =78″-3′clear(cast against and permanently exposed to earth)
-0.375″ (#6 bar/2) = 74.625″

$$As = \frac{0.85 f'c\, bd}{fy}\left[1-\sqrt{1-\frac{2\ Mu\ (12''/ft)}{0.85\ f'c\ \varnothing\ bd^2}}\ \right]$$

$$As = \frac{(0.85)(3)(16'')(74.625'')}{60}\left[1-\sqrt{1-\frac{2\times(156.9\ ft\text{-}kip)(12''/ft)}{(0.85)(3\ ksi)(0.9)(16'')(74.625'')^2}}\right] = 0.47\ in^2$$

$$As\ (min.) = \frac{(1.7)(h^2)b\sqrt{fc'}}{d\ fy} = \frac{(1.7)(78^2)(16)\sqrt{3000}}{(74.625'')(60000)} = 2.02\ in^2 > 0.47\ in^2$$

$$As\ (min.) = \frac{4}{3}\ As = \frac{4}{3}\times 0.47 = 0.627\ in^2 < 0.88\ in^2 (= 2\text{-}\#6\ bars)$$

Use 2-#6 Bars is adequate.

DESIGN EXAMPLES (CONT.)
EXAMPLE 2:

Calculate the abutment movement, overturning, and individual pile loads of the abutment shown in Figure 5. All piles are HP 12x53 with allowable pile axial loads of 70 tons (140 kips). The allowable abutment movement at the top of backwall is 1/8". Four loading cases I, II, III, IV are considered in accordance with this memo. Use Linear Subgrade Modulus Method (see Figures 1, 2 and 3 for estimating pile lateral stiffness and equivalent cantilever pile length). Soil friction angle ϕ of 30 degrees is assumed. The axial stiffness, K_a, of each pile is assumed to be equal to 2294 kips/in.

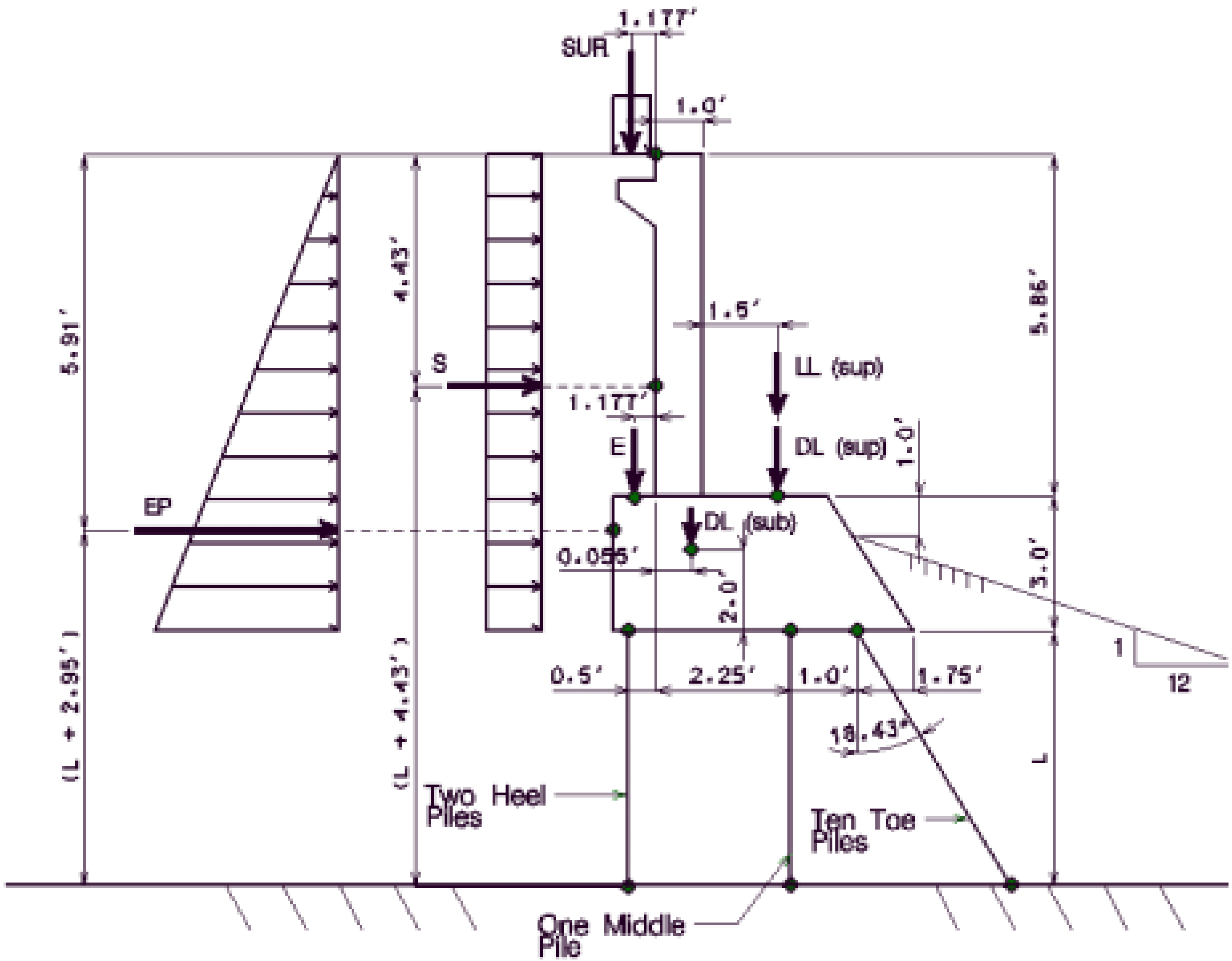


Figure 5. Non-integral End Bent

Given:	
Equivalent soil fluid pressure, EP	= 75.0 kips
Horizontal live load surcharge, S	= 33.81 kips
Vertical live load surcharge, SUR	= 1.68 kips
Substructure dead load, DL (sub)	= 200.3 kips
Superstructure dead load, DL (sup)	= 173.9 kips
Superstructure live load, LL (sup)	= 215.2 kips
Earth fill dead load, E	= 1.446 kips

Solution

1) *Find the lateral stiffness of piles with fixed pile-head (no rotation allowed):*
Soil friction angle ϕ, is 30 degrees, from Figure 1, the subgrade coefficient, f = 12 lbs/in.^{3}

The average pile embedment length is about 2' < 5'. Then, use embedment length of zero feet in Figure 3 to calculate pile-head lateral stiffness, K_δ. Bending stiffness of pile HP 12x53 is equal to EI = (29000*393) = 11397000 kips-in.^{2} = 1.1×10^{10} lbs-in.^{2}. From Figure 3, K_δ is equal to 6.0×10^4 lbs/in. = 60 kips/in.

2) *Structural model:*
The equivalent cantilever pile length, L, can be obtained by using the following equation;

$$K_\delta = \frac{12EI}{L^3}$$

$$L = \left(\frac{12EI}{K_\delta}\right)^{1/3} = \left(\frac{12x11397000}{60}\right)^{1/3} = 131.6 \text{ in.} = 10.97 \text{ ft.}$$

Thus, the structural model used in STRUCT3D is shown in Figure 6 with the equivalent cantilever pile length of 10.97 feet. The corresponding equivalent axial rigidity, A_e*E, is equal to K_a*L = (2294*131.6) = 301890.4 kips. From Equation (5), A_e = 10.41 in.^{2}.

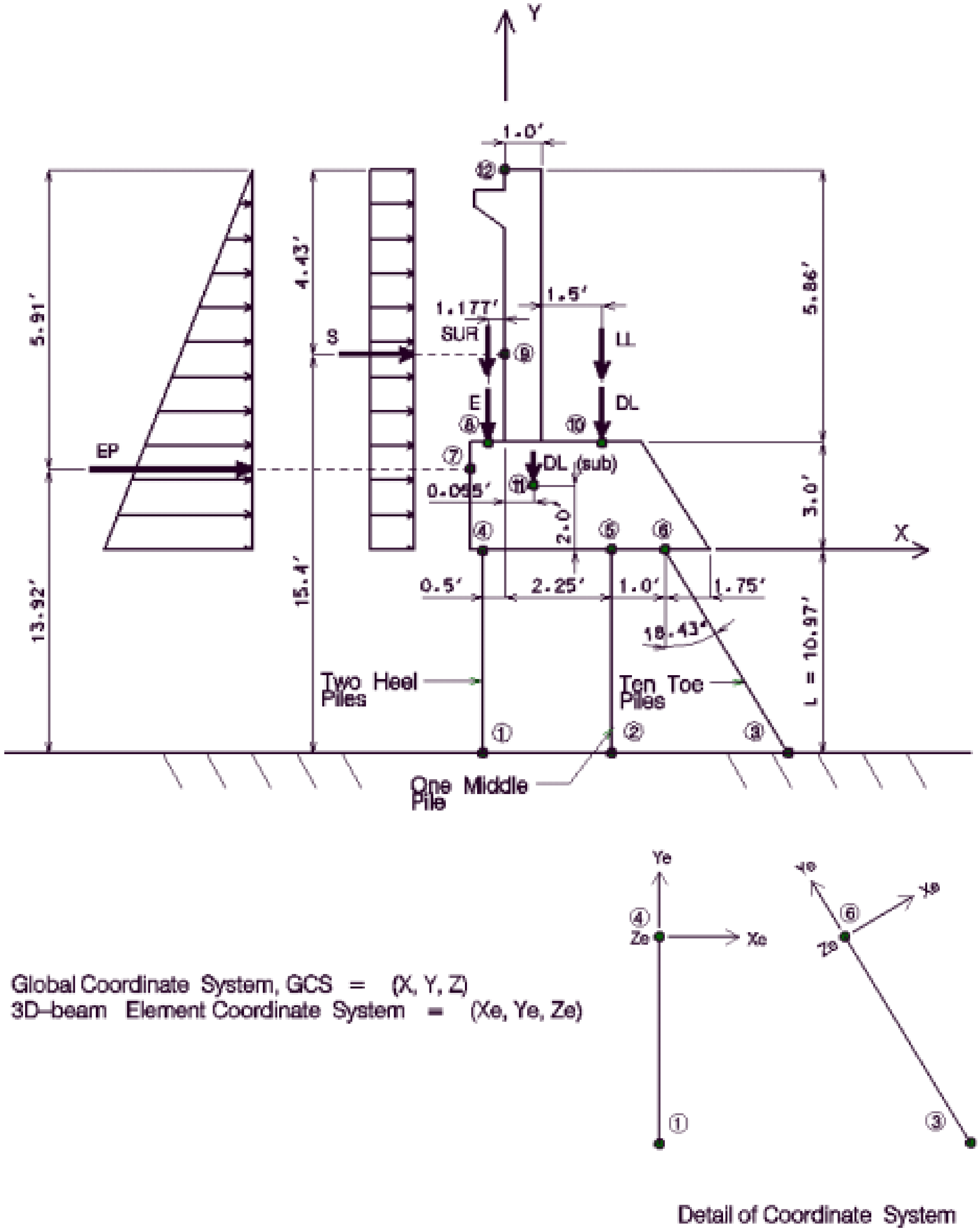


Figure 6. Structural Model in STRUCT3D Program

The structural model in Figure 6 consists of three equivalent cantilever piles connected to a rigid body at joints 4, 5, and 6. The equivalent moment of inertia and cross-section areas of heel, middle, and toe piles are:

	2 Heel Piles	1 Middle Pile	10 Toe Pile
Moment of Inertia, I (in.^{4})	786	393	3930
Equivalent Length, L (ft.)	10.97	10.97	10.97
Equivalent Pile Area, A (in.^{2})	20.82	10.41	104.1

3) *Check abutment movement:*
The analytical output from the computer program STRUCT3D shows that the maximum abutment movement (away from backfill) at the bottom of the beam cap is 0.015" which is less than allowable movement of 1/8". Therefore, deadman anchorage is not required in this example. Also note that the maximum abutment movement (toward backfill) at the top of backwall is 0.15" which is less than ¼". There is not any movement away from the backfill at the top of backwall for all loading cases.

The input data file for this example is available in the drive I:\gerj\stress\exam5c.str. You can copy and modify it for your project.

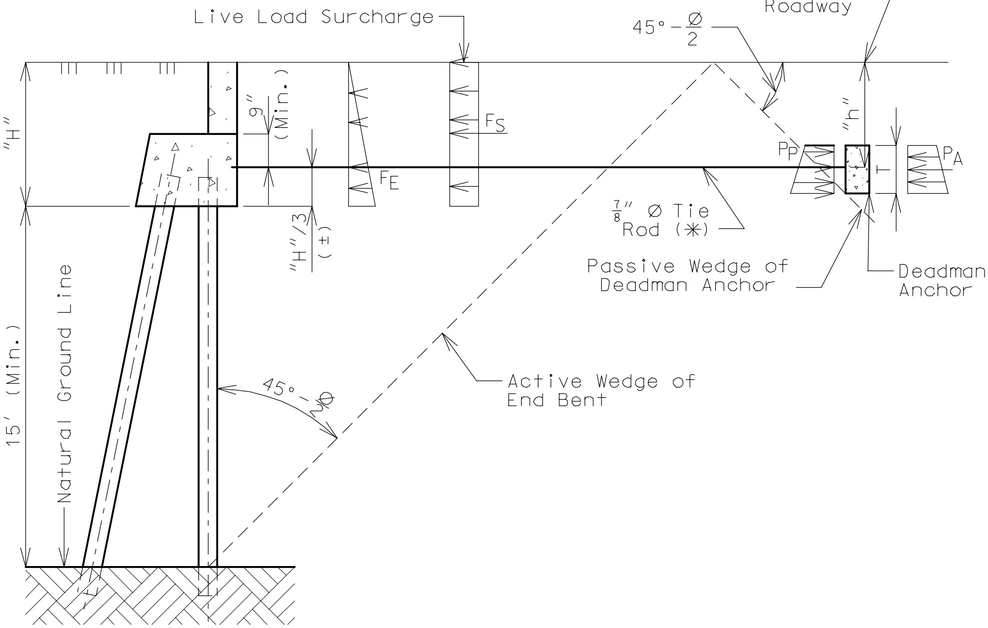
4) *Pile capacity check:*
From STRUCT3D output, maximum pile compressive loads are;
P_{heel} = 296.6/2 = 148.3 kips = 74 tons < 87.5 tons **O.K.** (125% of 70 tons, load case IV only)
P_{middle} = 114.2 kips = 57.1 tons < 70 tons **O.K.**
P_{toe} = 388.2/10 = 38.8 kips = 19.4 tons < 70 tons **O.K.**

5) *Check abutment overturning:*
Check critical plane at 10.97 feet below the bottom of beam cap.
For Case I,
Resisting moment, Mr = (1.446)(8.08) + (200.3)(6.85) + (173.9)(4.405) = 2149.7 kips-feet
Overturning moment, Mo = (75)(13.92) + (33.81)(15.4) = 1564.9 kips-feet
SF = Mr / Mo = 2149.7/1564.9 = 1.37 > 1.2 **O.K.**

For Case II,
Resisting moment, Mr = 2149.7 + (215.2)(4.405) = 3097.6 kips-feet
Overturning moment, Mo = (75)(13.92) + (33.81)(15.4) = 1564.9 kips-feet
SF = Mr / Mo = 3097.6/1564.9 = 1.98 > 1.5 **O.K.**

DEADMAN ANCHORS

Design Assumptions



Length of Deadman = $(F_E + F_S) / (P_P - P_A)$

Number of tie rods required = $(F_E + F_S) / F_R$

P_A = Active earth pressure on deadman, in lb/ft = $(120\ \text{pcf})K_A hT$

(✳✳) P_P = Passive earth pressure on deadman, in lb/ft = $(120\ \text{pcf})K_P hT$

F_E = Earth pressure on end bent, in lb = $0.5(120\ \text{pcf})K_A H^2$(length of beam)

F_S = Surcharge on end bent, in lb = $(120\ \text{pcf})(2')K_A H$(length of beam)

$K_A = \text{Tan}^2(45° - Ø/2)$

$K_P = \text{Tan}^2(45° + Ø/2)$

(✳✳✳) F_R = 8.0 kips for 7/8" Ø tie rod and 10.50 kips for 1" Ø tie rods (Capacity of the tie rods based on a maximum skew of 30°.)

✳ If the number of 7/8" Ø tie rods causes too long of a deadman, then try 1" Ø tie rods.

✳✳ For seismic loads only, use P_P = 4 kips/sq.ft. as the ultimate capacity of compacted fill.

✳✳✳ For seismic loads only, the allowable stress in the tie rod may be taken as the yield stress of the rod.

Notes:

No more than 20% of deadman may fall outside of the roadway shoulders. To prevent more than 20% limit, using a deeper deadman to reduce its length. If this is not possible, the total passive pressure resistance should be calculated by summing the resistance from the different fill depths.

When deadman anchors are to be used, design the piles for a factor of safety of 1.0 for sliding and design deadman anchors to resist all horizontal earth forces with a factor of safety of 1.0. This will result in a factor of safety for sliding of 2.0. For special cases, see the Structural Project Manager.

DEADMAN ANCHORS (CONT.)

Design Example

Assume:

Roadway width = 36′, Out-Out slab width = 36′ + 2x16″ = 38.67′

Skew = 15°, Length of Beam = (38.67′)/(Cos 15°) = 40.03′

Beam depth = 3′-0″, Ø = 27°, H = 8.20′

$\frac{H}{3} = \frac{8.20'}{3} = 2.73'$

3′ − 2.73′ = 0.27′ < 9″, use 9″,

h = H − (Beam depth) + 9″ = 8.20′ − 3′ + 0.75′ = 5.95′

Assume T = 2′-0″ (Deadman anchor depth)

Determine Earth and Surcharge Forces

$K_A = Tan^2(45° - Ø/2) = Tan^2(45° - 27°/2) = 0.3755$

$K_P = Tan^2(45° + Ø/2) = Tan^2(45° + 27°/2) = 2.6629$

$F_e = \frac{1}{2}(120\ K_A H^2)$(Length of Beam)

= (60 lb./cu.ft.)(0.3755)(8.20′)²(40.03′)
= 60,842 lbs.

$F_S = (2')\ (120\ K_A H)$ (Length of Beam)

= (240 lb/sq.ft.) (0.3755)(8.20′)(40.03′)
= 297,582 lbs.

$P_A = 120\ K_A h\ T$

= (120 lb/cu.ft.) (0.3755)(5.95′)(2.0′)
= 536 lbs. per foot of Deadman

$P_P = 120\ K_P h\ T$

= (120 lb/cu.ft.)(2.6629)(5.95′)(2.0′)
= 3,803 lbs. per foot of Deadman

Determine number of Tie Rods required

Try $\frac{7}{8}$″ Ø Rods: F_R = 8.0 kips

Number of Rods required = $(F_E + F_S)/F_R$ = (60,642+29,582)/8,000 = 11.29

Use 12-7/8″ Ø Tie Rods.

Determine length of Deadman

Length of Deadman required = $(F_E + F_S)/(P_P - P_A)$ = {(60.642+29.582) lbs}

/{(3,803- 536) lb/ft} = 27.62′

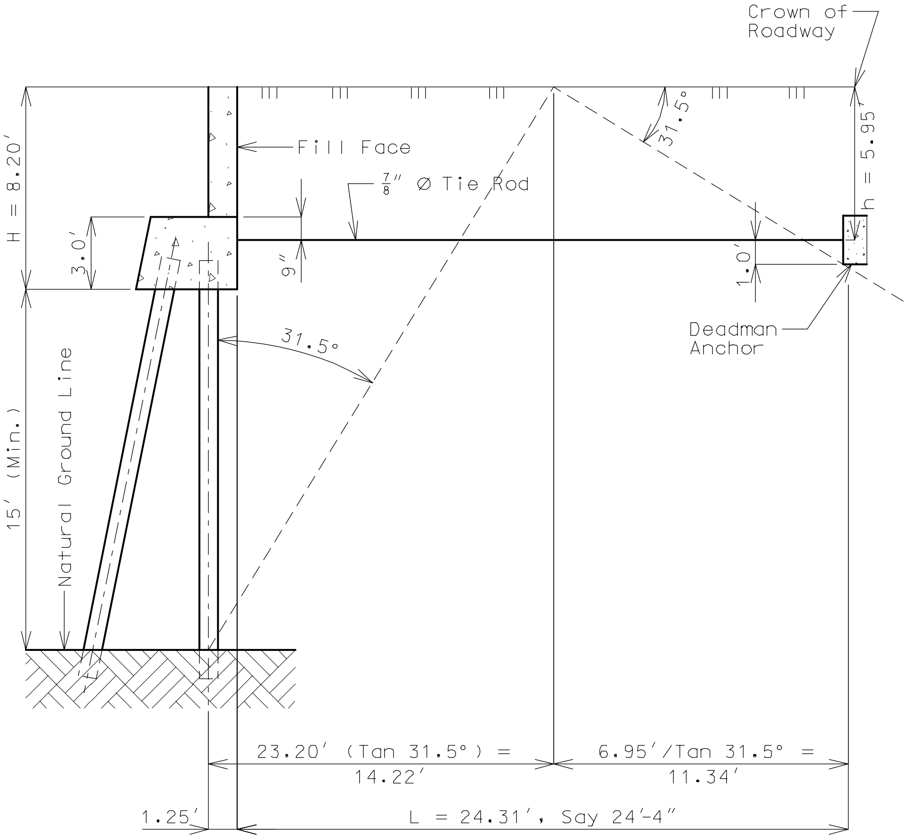
Tie Rod spacing = (27.62′-2.0′)/11 = 2.33′, say 2′-4″>12″ minimum, ok.

Length of Deadman provided = (2′-4″) (11) + 2.0′ = 27′-8″

DEADMAN ANCHORS (CONT.)

Design Example (Cont.)

Determine location of Deadman from Fill Face of End Bent



$\varnothing = 27°$

$45° - \frac{\varnothing}{2} = 31.5°$

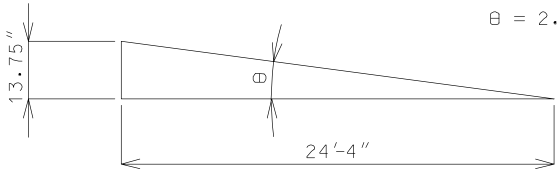
DEADMAN ANCHORS (CONT.)

Design Example (Cont.)

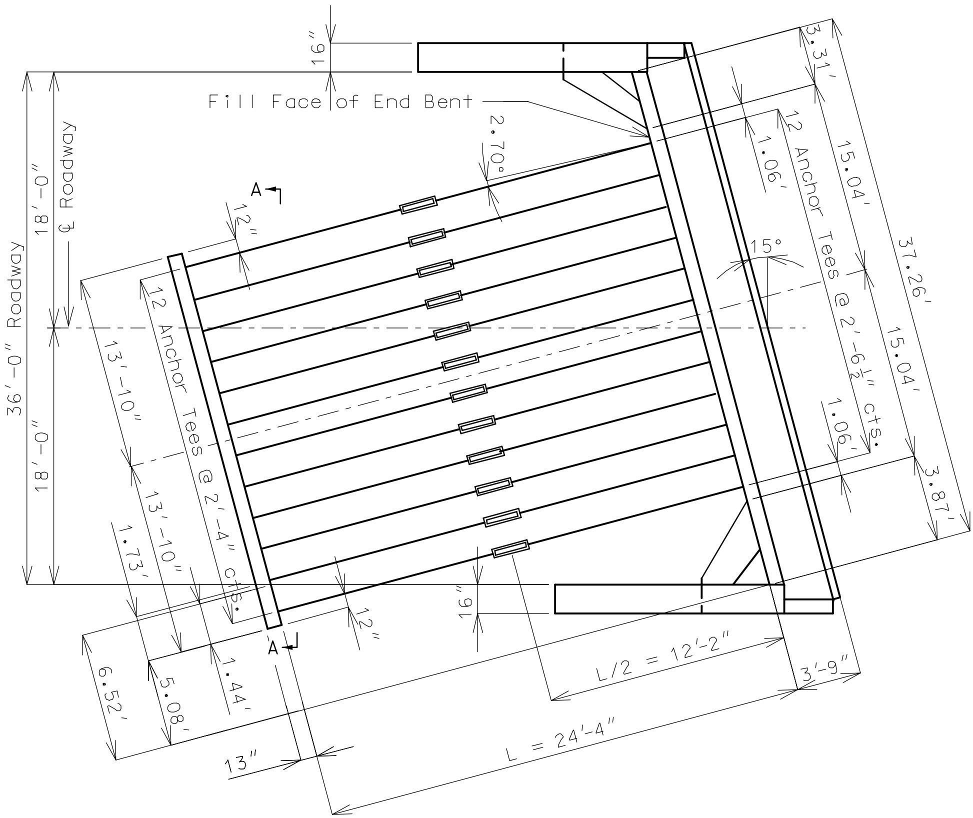
1) Check tie rod skew angle at Fill Face of End Bent

(5.5 spacing)(30.5″-28″) = 13.75″, tan θ = 13.75″/(24.33x12″) = 0.471

θ = 2.70°<30°, tie capacity ok.



2) Check criteria for Deadman Anchors extending into Fill Slope



A) Extension of Deadman into Fill Slope

Length of Deadman extending into Fill Slope = 1.08′tan15° + (13.83′-((15.04′+3.87′)-24.33′tan15°)) = 1.73′

0.2 (Length of Deadman) = 0.2 (27.67′) = 5.53′

1.73′< 5.53′

Length of Deadman extending into Fill Slope < 0.2 (Length of Deadman), ok

Note: See the following sheet for Section A-A Details.

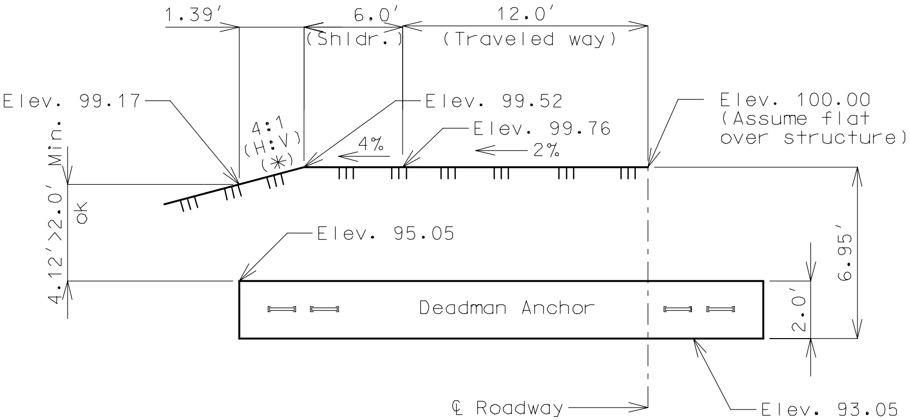
DEADMAN ANCHORS (CONT.)

Design Example (Cont.)

2) Check criteria for Deadman Anchors extending into Fill Slope (Cont.)

B) Cover of Deadman in Fill Slope

1.44′x(cos15°) = 1.39′



SECTION A-A
DETAIL AT FILL SLOPE

Note:

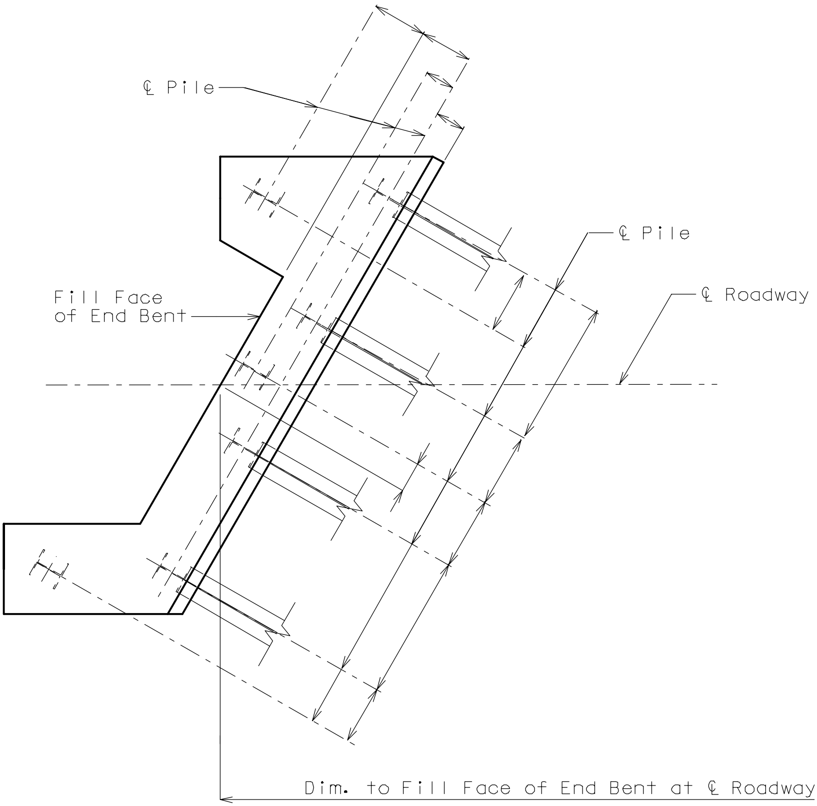
(✳) Fill slope shown is for illustration purpose only, see roadway plans.

See page 1.4-4 for the location of Section A-A

FRONT SHEET

Notes: The following are details and dimensions for the plan view on the Front Sheets.

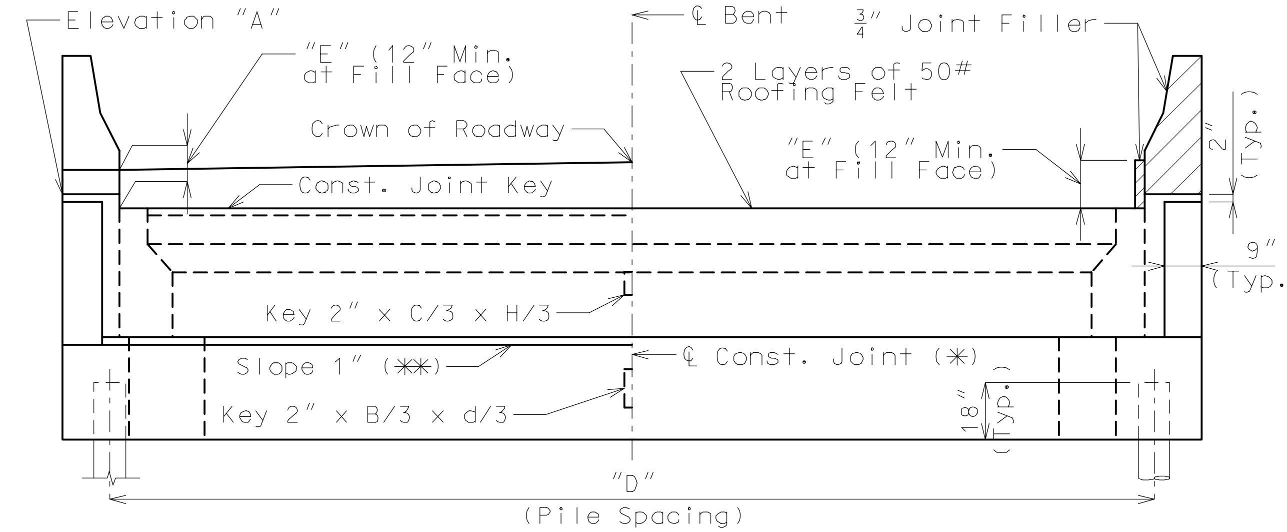
Details for unsymmetrical roadways will require dimensions. tying Centerline Lane to Centerline Structure.



NON-INTEGRAL END BENTS

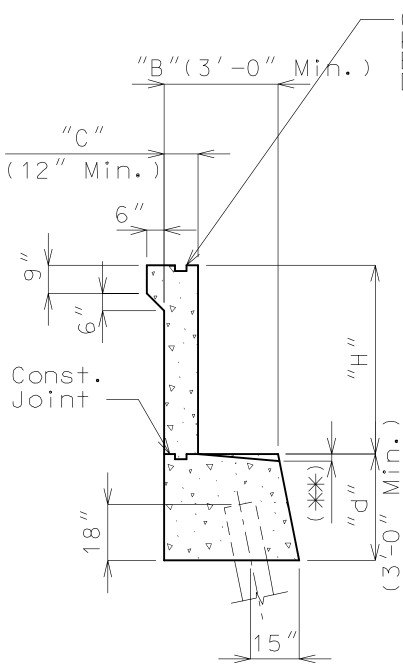
Steel piles shown, CIP piles similar.
Left advance shown, right advance similar.

WIDE FLANGES BEAMS, PLATE GIRDERS & PRESTRESS GIRDERS

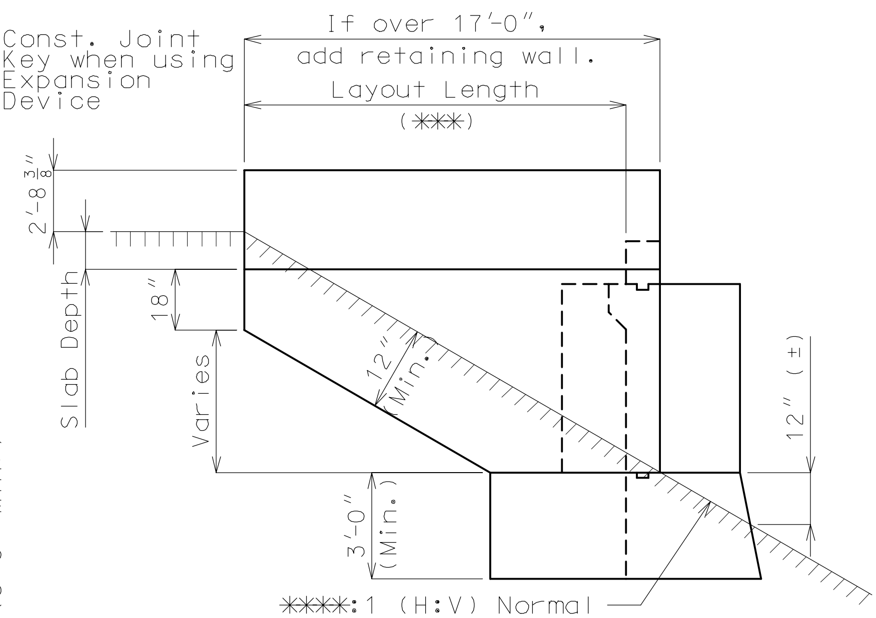


EXPANSION DEVICE NO EXPANSION DEVICE

Note: Provide a minimum of 6" CL. from outside edge of pile to face of beam.



PART SECTION AT CENTERLINE



ELEVATION OF SAFETY BARRIER CURB

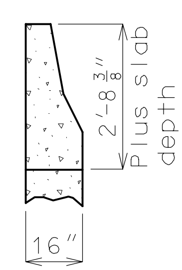
✱ When the total length of a beam and backwall exceeds 60'-0", use a keyed construction joint at or near CL bent as shown, preferably located at ¼ point between piles. Maximum key length equals 18". For multiple keys make total key length equal to H/3 or d/3.

✱✱ Slope top of beam 1" when using expansion devices.

✱✱✱ Wing layout length shall be rounded to the next higher foot. See the profile sheet for length of wing to fill face.

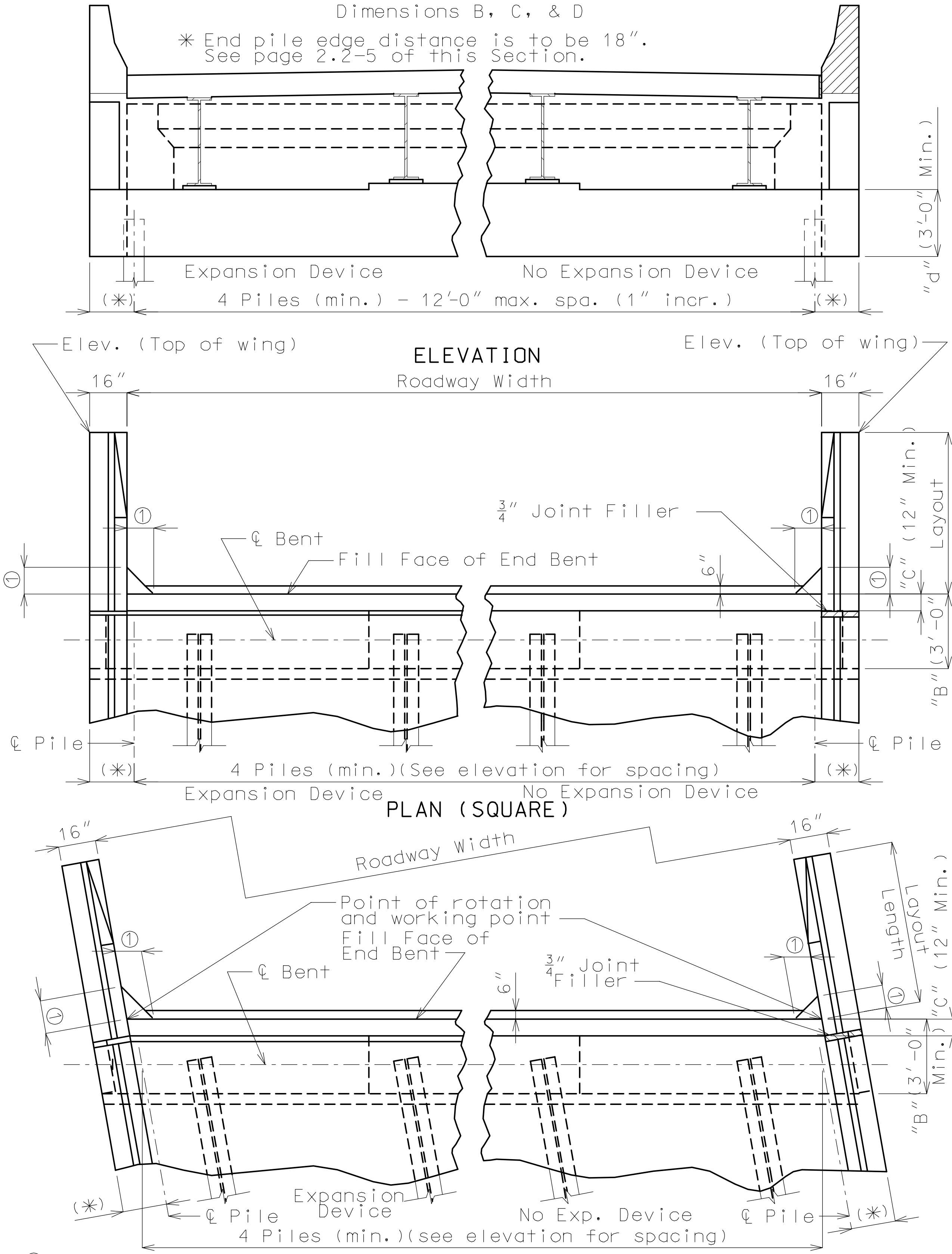
✱✱✱✱ See Design Layout for maximum slope of spill fill.

Note: For dimensions not shown, see the following sheets.



PART SECTION THRU 16" BARRIER CURB

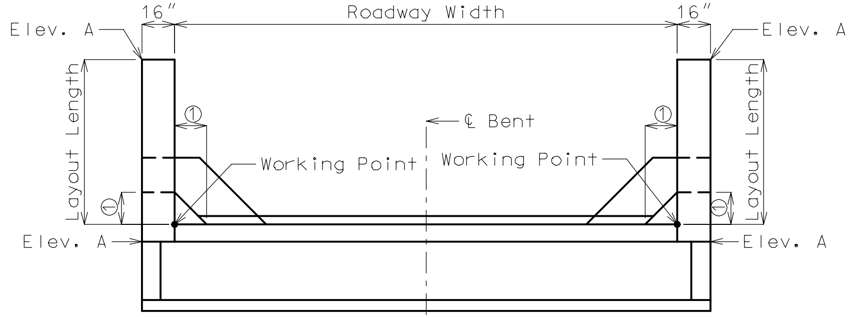
WIDE FLANGES BEAMS, PLATE GIRDERS & PRESTRESS GIRDERS (CONT.)



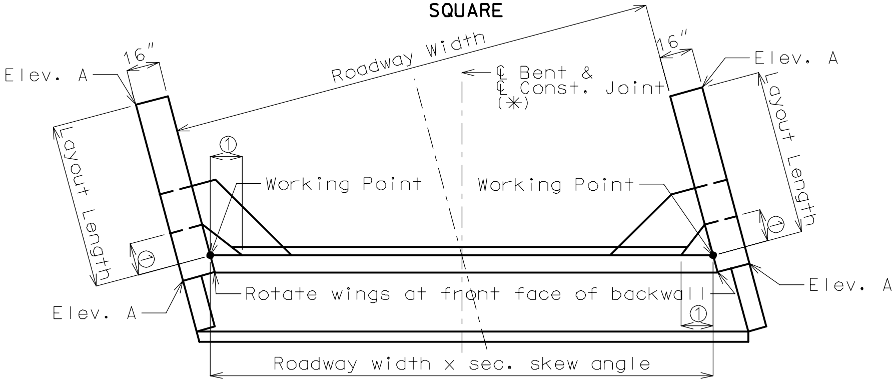
① See this sec. 3.76, page 2.3-1 for wing brace details.

WIDE FLANGES BEAMS, PLATE GIRDERS & PRESTRESS GIRDERS (CONT.)

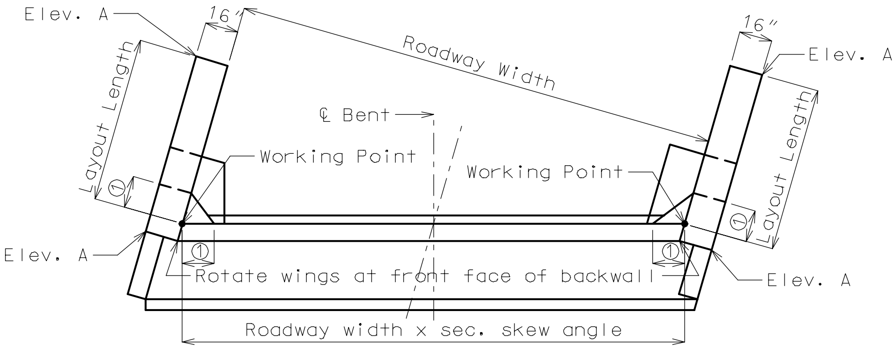
WING LAYOUT, ELEVATION A



SQUARE



SKEWS THRU 15°- LEFT ADVANCE SHOWN

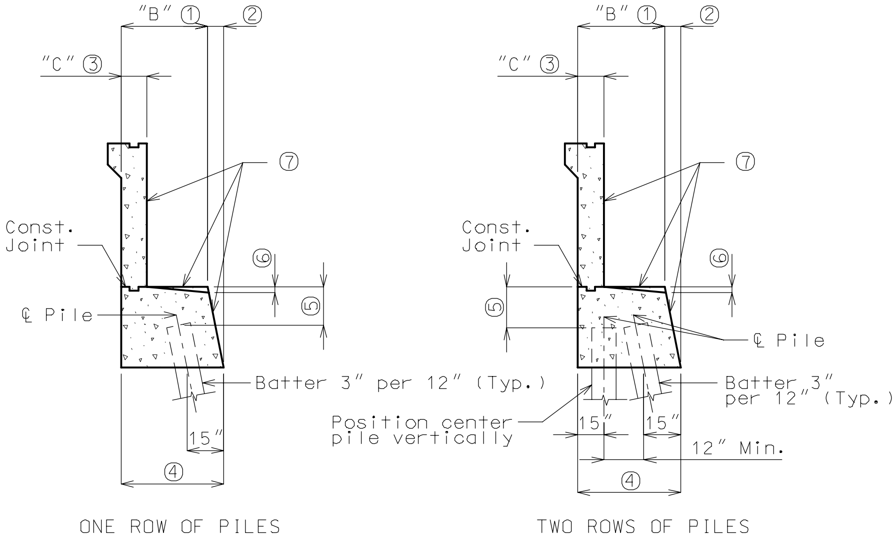


SKEWS OVER 15°- RIGHT ADVANCE SHOWN

① See this sec. 3.76, page 2.3-1 for Wing Brace details.

✳ When total length of beam and backwall exceeds 60'-0", use a keyed construction joint at or near the center-line of bent as shown, preferably located at the 1/4 point between piles.

WIDE FLANGES BEAMS, PLATE GIRDERS & PRESTRESS GIRDERS (CONT.)
DIMENSIONS B & C

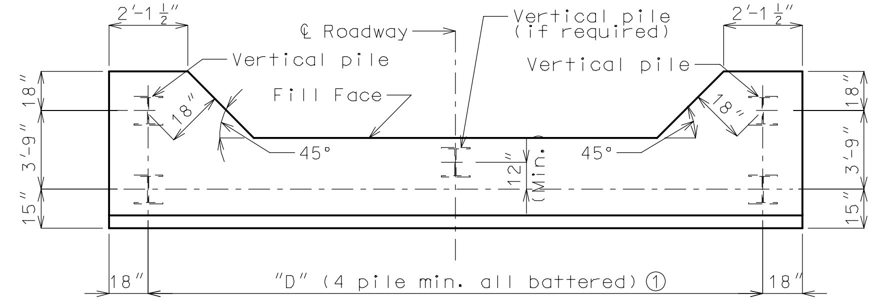


SECTION THRU BENTS

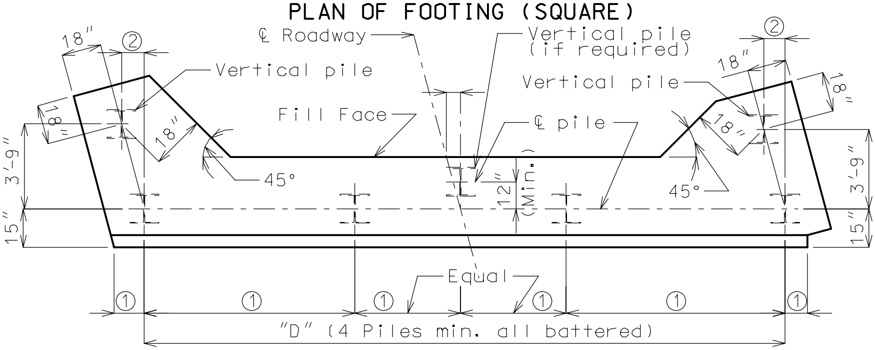
Note: Provide a minimum of 6" cl. from outside edge of pile to face of beam.

① 3'-0" min. (1" Increments).
② When this dimension is less than 6", make the front face vertical.
③ Use 12" min. thickness. Refer to sec. 3.76.3 Reinforcement of End Bent.
④ 3'-6" min. (1" Increments).
⑤ Check clearance of anchor bolt well to top of pile. Increase beam depth, if needed.
⑥ Slope top of beam 1" when using expansion device only.
⑦ Apply protective coating (See Special Provisions) to the backwall, top of beam cap and front face of beam cap when using expansion devices.

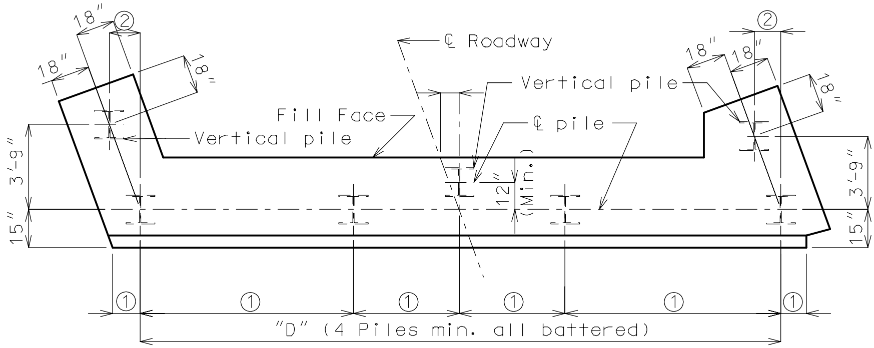
WIDE FLANGES BEAMS, PLATE GIRDERS & PRESTRESS GIRDERS (CONT.)
DIMENSIONS D



5 Piles-position center pile vertically
PLAN OF FOOTING (SQUARE)



PLAN OF FOOTING (SKEWS THRU 15°- LEFT ADVANCE)



PLAN OF FOOTING (SKEWS OVER 15°- LEFT ADVANCE)

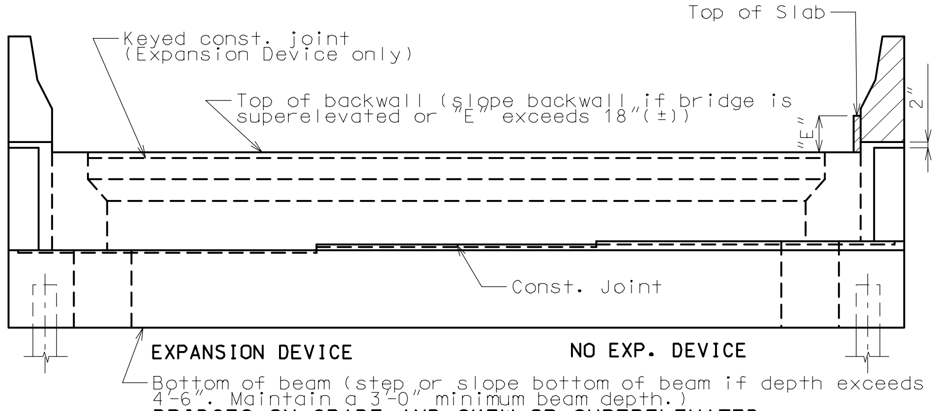
① End pile edge distance is to be 18". Max. pile spacing = 12'-0".
Pile spacing increments to be dimensioned as computed(no set increment).

② Show on plans.
For exceptions to these dimensions, see the Structural Project Manager.

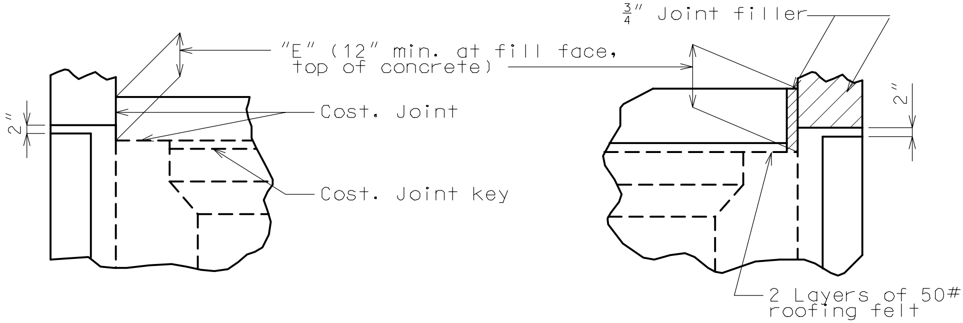
Steel piles shown, CIP piles similar.

Left advance shown, right advance similar.

WIDE FLANGES BEAMS, PLATE GIRDERS & PRESTRESS GIRDERS (CONT.)
DIMENSIONS E



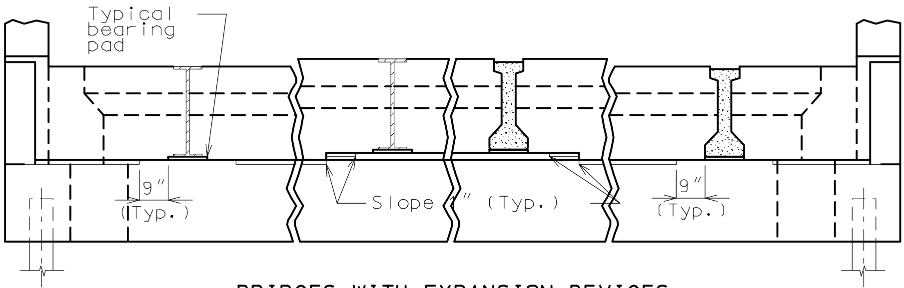
BRIDGES ON GRADE AND SKEW OR SUPERELEVATED
(WITH OR WITHOUT EXPANSION DEVICE)



EXPANSION DEVICE

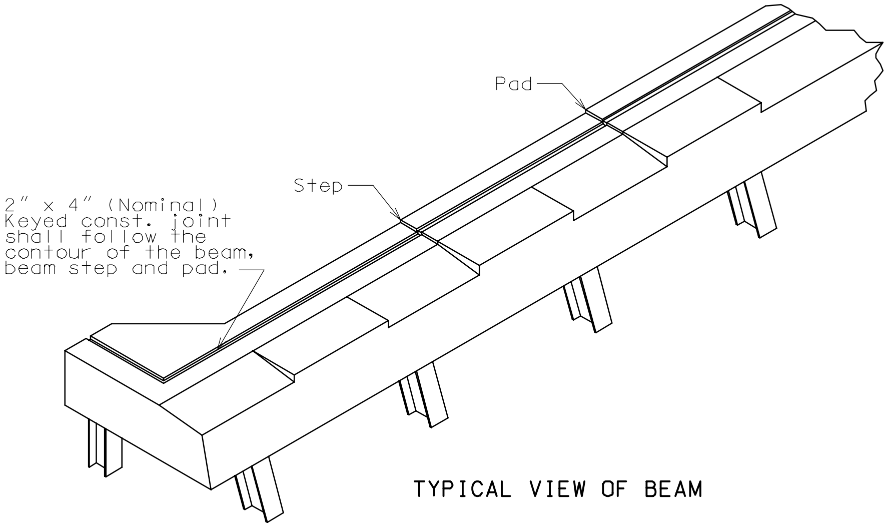
NO EXPANSION DEVICE

Note: Provide a minimum of 6" clearance from outside edge of pile to face of beam.

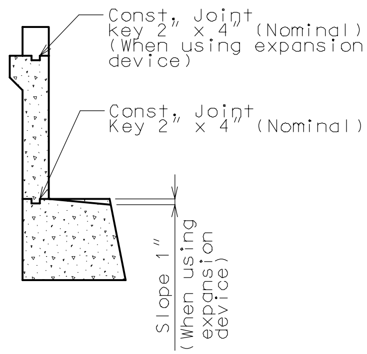


BRIDGES WITH EXPANSION DEVICES

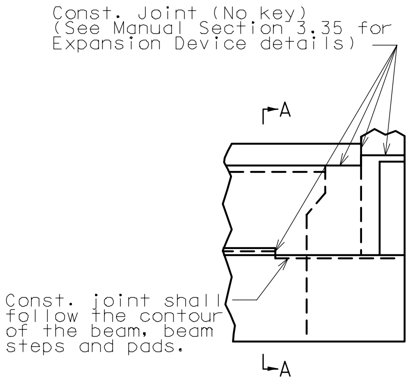
WIDE FLANGES BEAMS, PLATE GIRDERS & PRESTRESS GIRDERS (CONT.)
CONSTRUCTION JOINTS AND KEYS



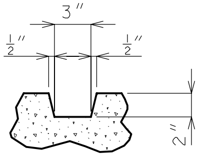
TYPICAL VIEW OF BEAM



PART SECTION A-A



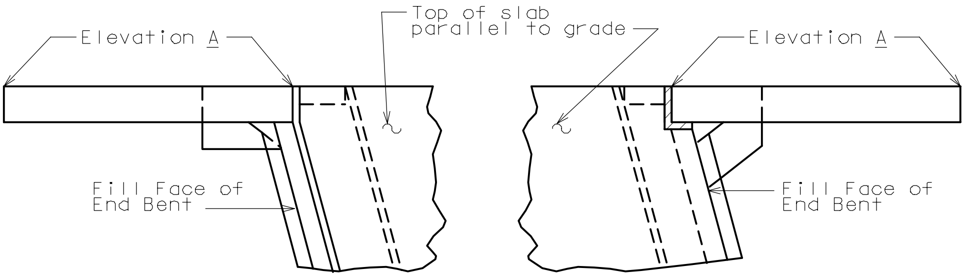
PART ELEVATION



DETAIL OF KEYED CONST. JOINT

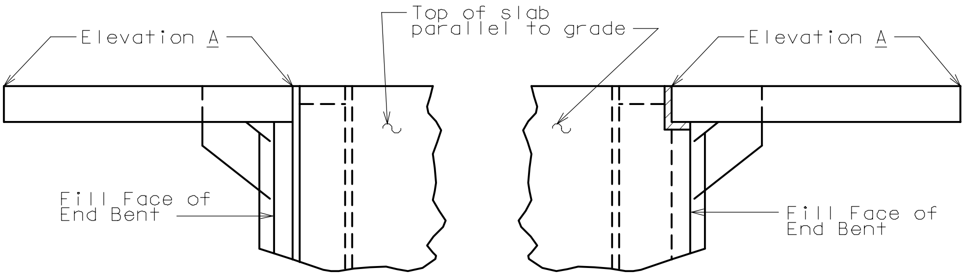
WIDE FLANGES BEAMS, PLATE GIRDERS & PRESTRESS GIRDERS (CONT.)

SAFETY BARRIER CURB AND ELEVATION A



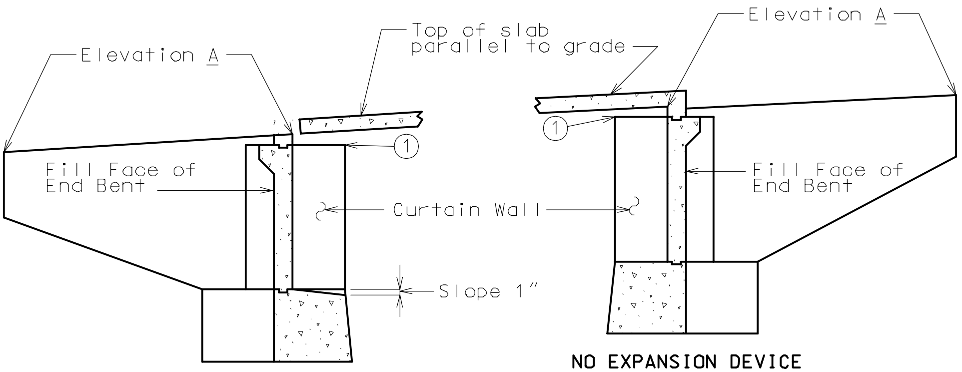
EXPANSION DEVICE   NO EXPANSION DEVICE

PART PLAN (SKEWED)



EXPANSION DEVICE   NO EXPANSION DEVICE

PART PLAN (SQUARE)



NO EXPANSION DEVICE

EXPANSION DEVICE

1 Top of curtain wall shall not intrude bottom of slab. If necessary slope top of curtain wall.

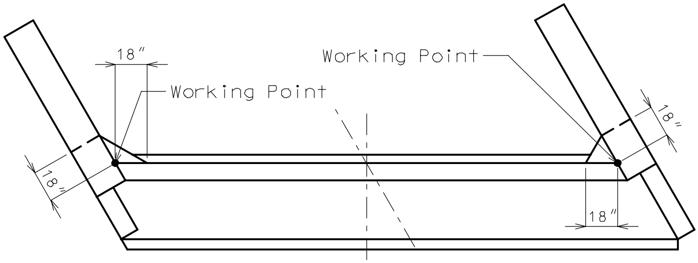
SECTIONS NEAR LEFT WING

Elevation A - Wing elevation is determined at this point for bridges on grade.

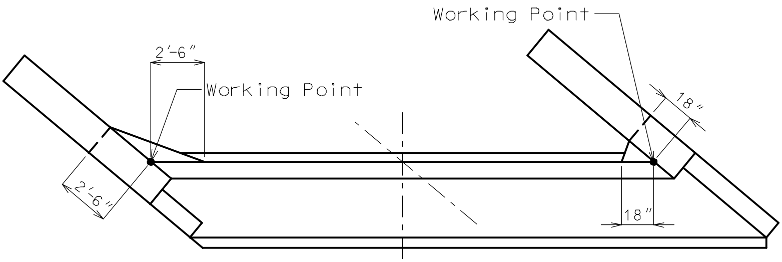
WING BRACE DETAILS

Dimensions

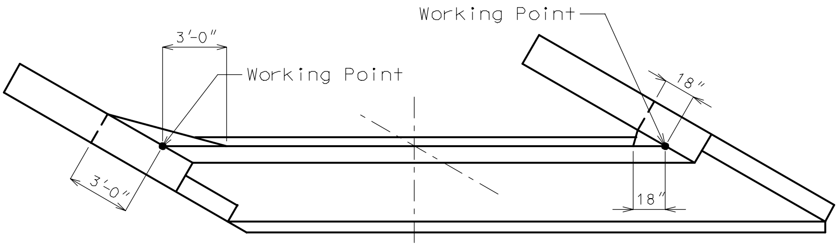
The wing brace dimensions will only vary on the wing with obtuse angle. The wing with the acute angle will always be 18".



SKEWS THRU 0° TO 45°



SKEWS THRU 45°00'01" TO 55°



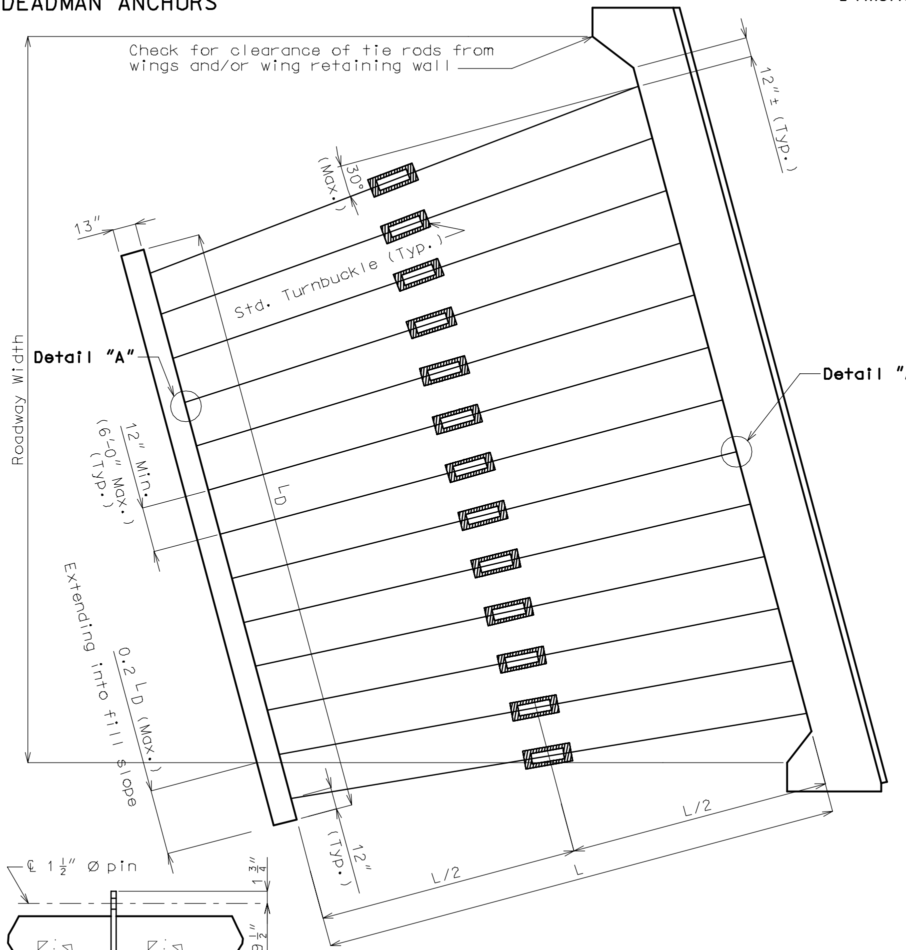
SKEWS THRU 55°00'01" AND OVER

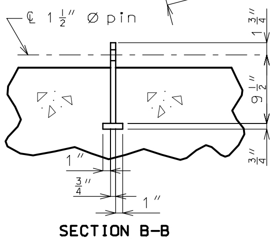
Note:

Left advance shown, right advance similar.

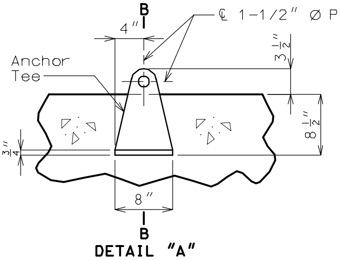
DEADMAN ANCHORS

Dimensions



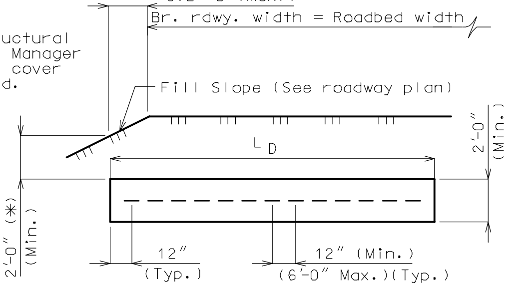


SECTION B-B



DETAIL "A"

(✻)See Structural Project Manager if less cover provided.

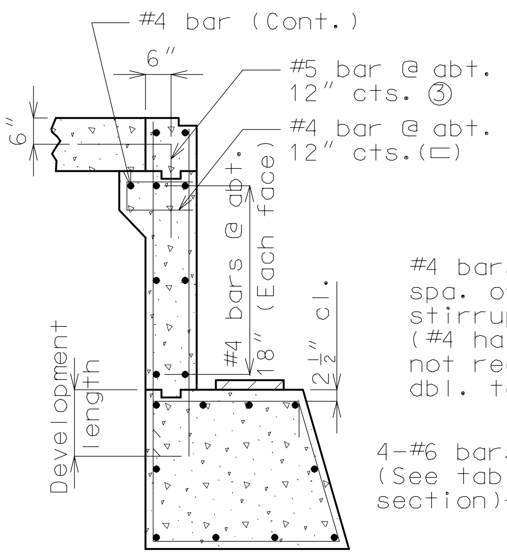


DETAIL AT FILL SLOPE

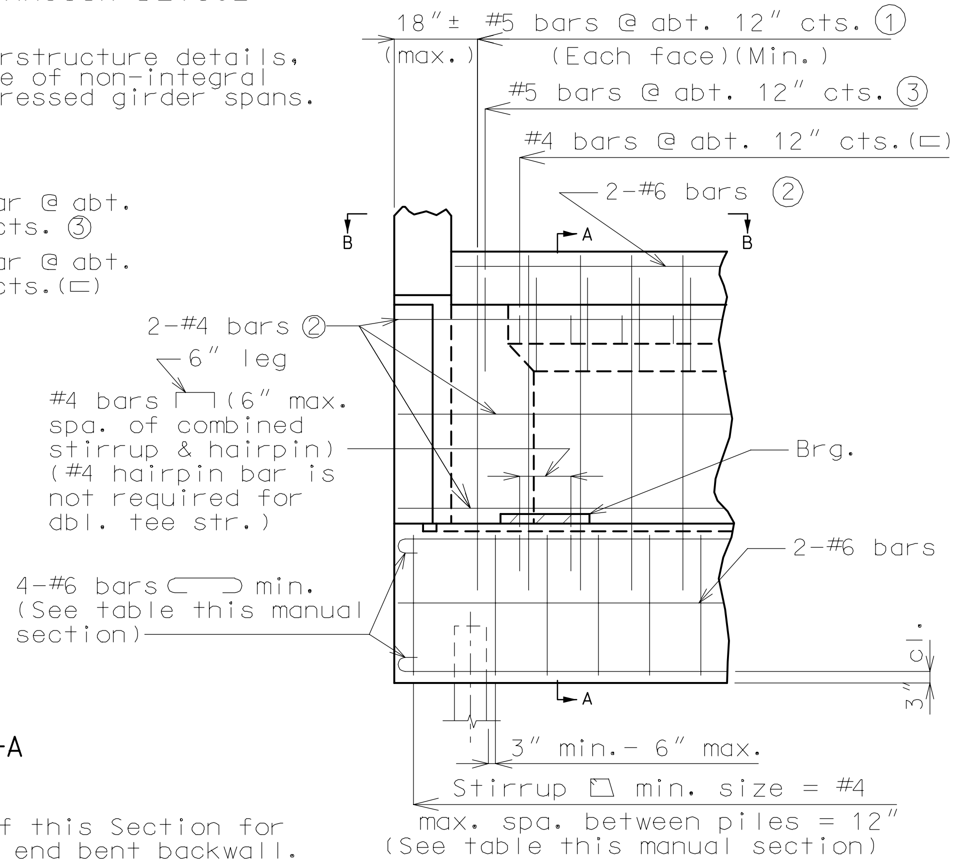
WIDE FLANGES, PLATE GIRDERS & PRESTRESSED GIRDERS
END BENT WITH EXPANSION DEVICE

Reinforcement

Note: Refer to superstructure details, Section 3.55 for use of non-integral end bents for prestressed girder spans.



SECTION A-A



PART ELEVATION

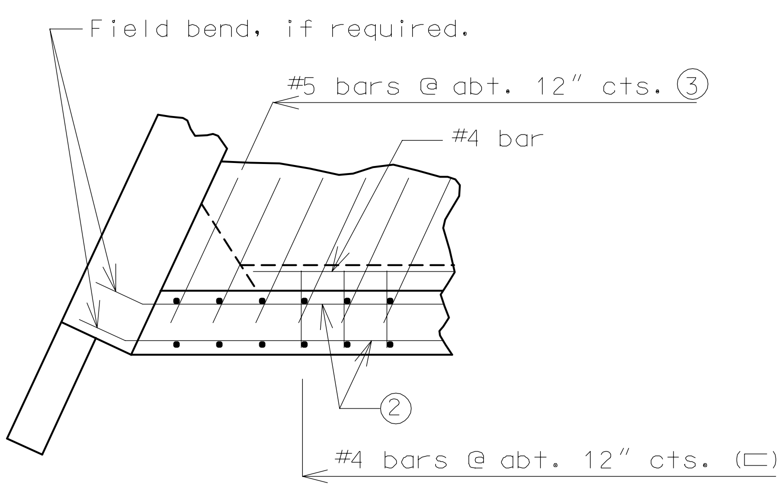
Notes:

① See page 4.1-7 of this Section for reinforcement of end bent backwall.

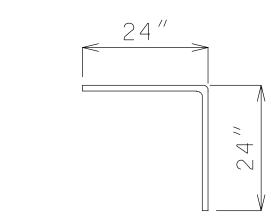
② #6-H bars and #4-H bars in backwall of skewed bridges shall be bent in field if required.

③ Center #5 bars in backwall.

Epoxy coat all reinforcing in end bents with expansion devices. See page 5.4-1 of Section 3.35 for details of protective coating and sloping top of beam to drain.



PART PLAN B-B

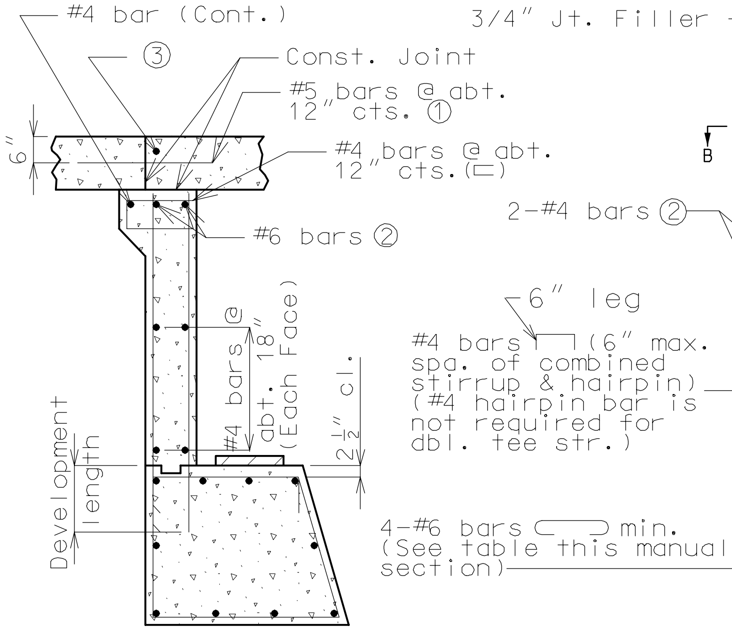


DETAIL OF #5 BARS
SHAPE 19

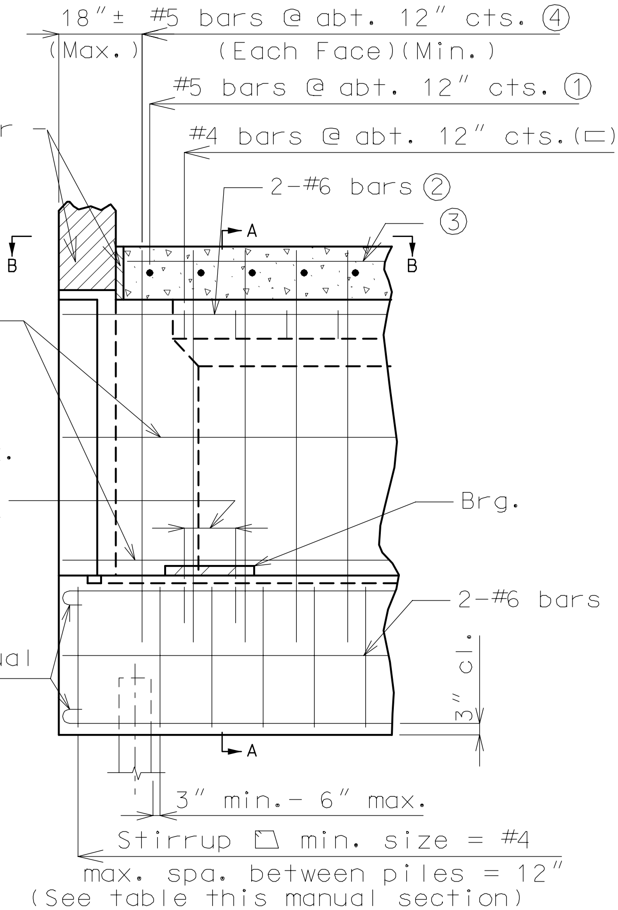
WIDE FLANGES, PLATE GIRDERS & PRESTRESSED GIRDERS
END BENT WITHOUT EXPANSION DEVICE

Reinforcement

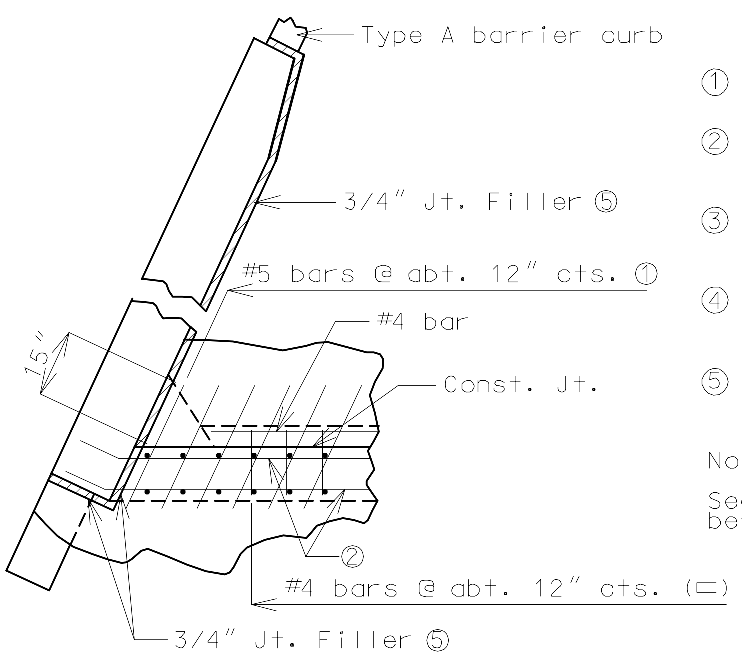
Note: Refer to superstructure details, Section 3.55 for use of non-integral end bents for prestressed girder spans.



SECTION A-A



PART ELEVATION



PART PLAN B-B

① #5 Dowel bars are 2'-6" long and placed parallel to ℄ rdwy.

② #6-H bars and #4-H bars in backwall of skewed bridges shall be bent in field.

③ For skewed bridges with no expansion device place a #4 bar along skew.

④ See page 4.1-7 of this section for reinforcement of end bent backwall.

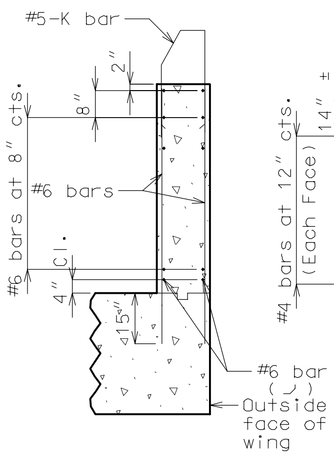
⑤ Seal joint with joint sealant. See special provisions.

Note:

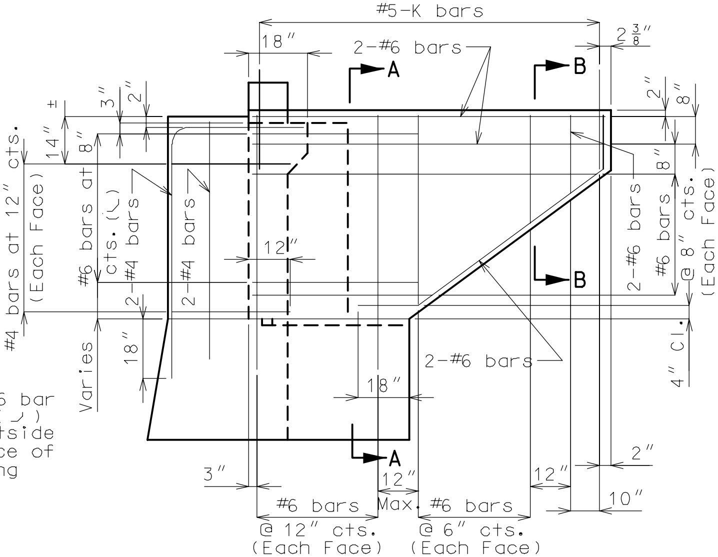
See Structural Project Manager before using this detail.

WIDE FLANGES, PLATE GIRDERS & PRESTRESSED GIRDERS
END BENT WING

Reinforcement



SECTION A-A



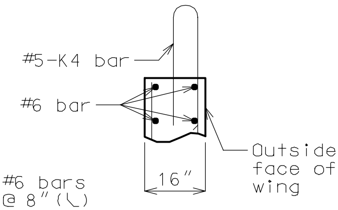
TYPICAL ELEVATION OF WING

Note:

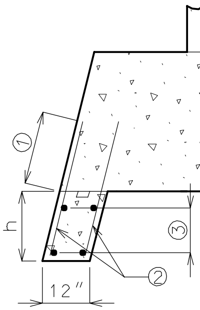
For spacing of K bars in safety barrier curb, see Bridge Manual Sec. 3.30.

1 Development length (See Bridge Manual Section 2.4).

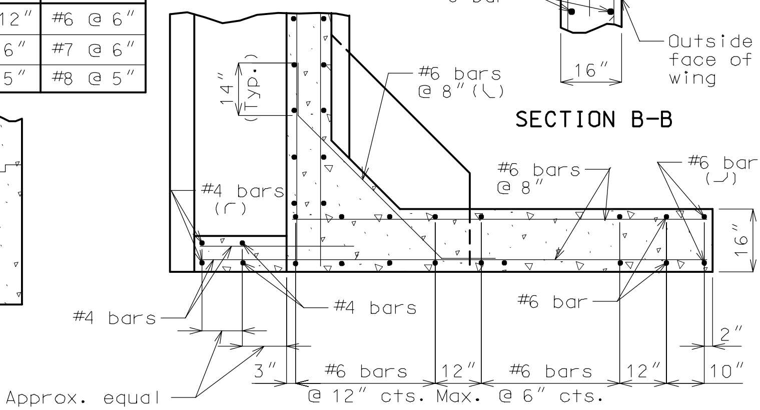
h	2	3
2' or less	#4 @ 12"	#6 @ 6"
Over 2' to 4'	#5 @ 6"	#7 @ 6"
Over 4' to 6'	#7 @ 5"	#8 @ 5"



SECTION B-B



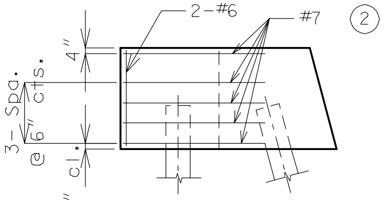
PART SECTION THRU BENTS
WITH PASSIVE PRESSURE



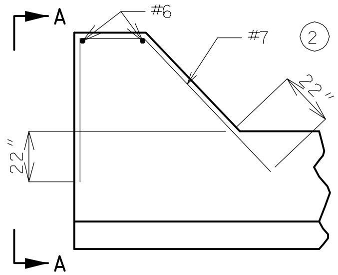
HORIZONTAL SECTION THRU WING
(K bars not shown for clarity)

WIDE FLANGES, PLATE GIRDERS & PRESTRESSED GIRDERS
END BENT BEAM HEEL

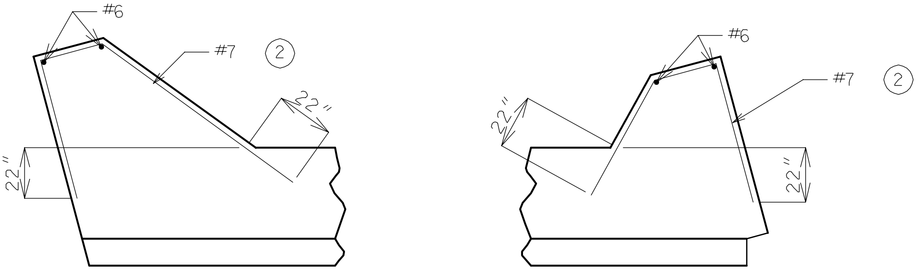
Reinforcement



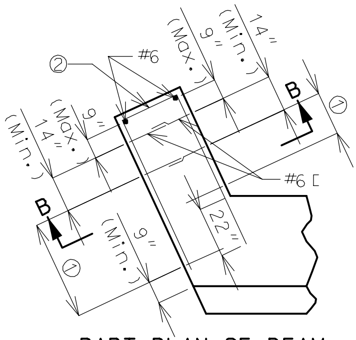
ELEVATION A-A (TYP.)

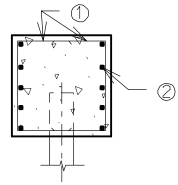


PART PLAN OF BEAM (SQUARE)

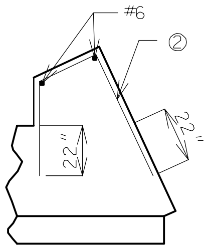


PART PLAN OF BEAM - SKEWS THRU 15° - LEFT ADVANCE SHOWN





SECTION B-B



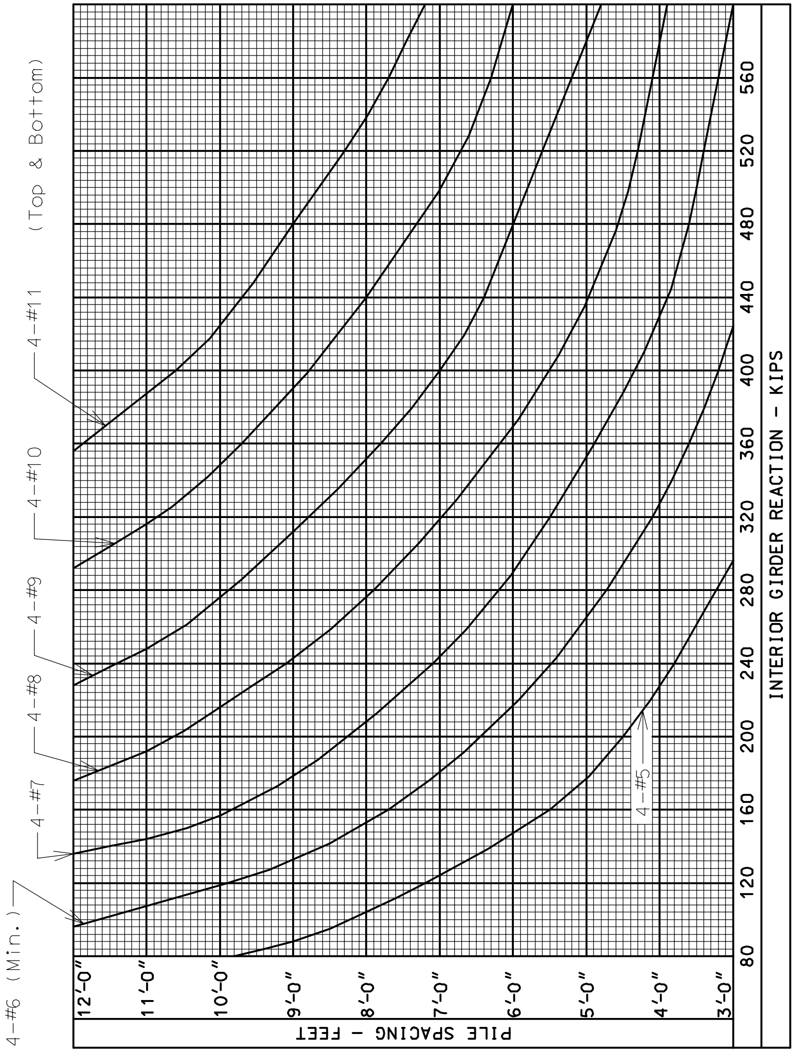
PART PLAN OF BEAM - SKEWS OVER 15° - LEFT ADVANCE SHOWN

Note:
Vertical spacing for #7 bars shown in Elevation A-A is typical for all types of end bent beams.
For a long distance between heel pile and bearing beam investigate for use of larger bars; e.g. larger skews where the shear line does not fall within the bearing beam.

Pile Load Not Greater	1 * Hair-Pin Stirrups	2 Horizontal Rebar around Heel Pile			
		Skew thru 30°	Skew 31° thru 45°	Skew 46° thru 60°	Skew over 60°
140 kips	#6 @ 9"	5 - #7	5 - #7	5 - #8	By Design
194 kips	#6 @ 6"	5 - #7	5 - #8	By Design	By Design

* Use 21" horizontal leg.

WIDE FLANGES, PLATE GIRDERS & PRESTRESSED GIRDERS Reinforcement
END BENT BEAM REINFORCEMENT CHARTS



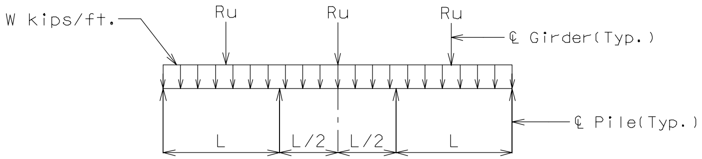
Note: Information for Beam Reinforcement is continued on the next sheet.

Int. Gdr. Reaction Ru = 1.3{DL(Superstr.)}+2.17{(Max. LL + I)(Shear Dist.✳)}

f'c = 3,000 psi. Fy = 60,000 psi.

(✳) If the computer output for max.(LL + I) is based on the moment distribution factor, do not revise the loads for the shear distribution factor.

Basic Assumption (continuous beam)

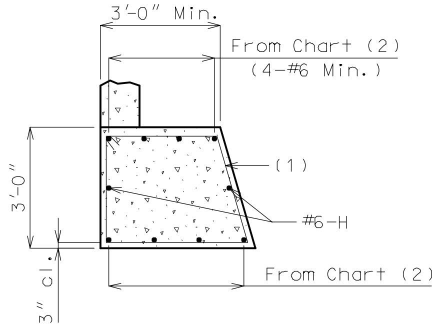


Ultimate Moment = $0.2RuL + 0.13WL^2$

Where: Ru = Ultimate Interior Girder Reaction, in kips;

L = Pile Spacing, in feet;

W = Uniform DL(beam, backwall, apron and 0.5 approach slab), in kips/ft.



(1) Stirrups	Max. Pile Load (Service Load)	Max. Ru (✻) (Factored Load)
#4 @ 12"	45 Ton	165 kips
#5 @ 12"	52 Ton	200 kips
#6 @ 12"	61 Ton	235 kips
#5 Dbl. @ 12"	70 Ton	285 kips

✻ Ru = Ultimate Interior Girder Reaction.

(2) Min. reinf.= p(min) = $1.7(h/d)^2(\sqrt{f'c}/fy)$
h=36", d=36"-3"-0.375"=32.625"

p(min)= $1.7(36''/32.625'')^2(\sqrt{3{,}000}/60{,}000)$ = 0.001890

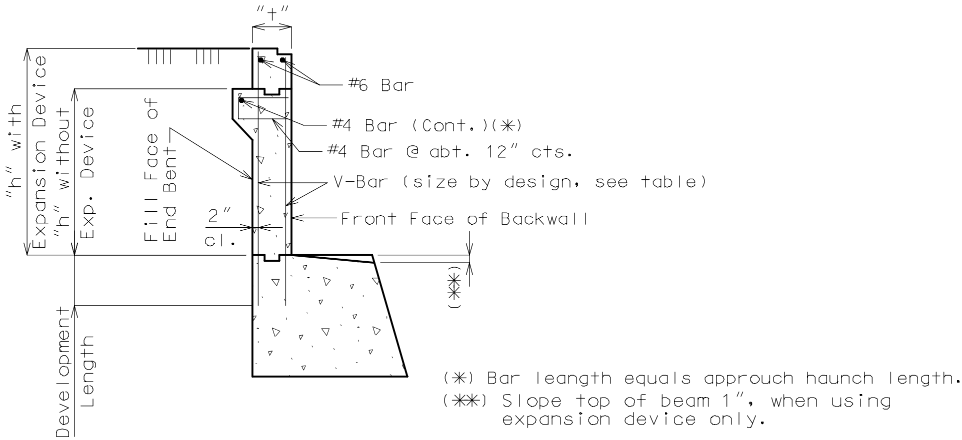
Min. As = (p min.)(bd) = 0.001890(36")(32.625") = 2.22 sq.in. (4-#7)
but need not exceed 1.333 time area required by analysis (chart).
(Use 4-#6 when CL.bearings are 12" or less on either side of CL.piles)

Note: Beam reinforcement was determined by load factor design procedures.

All stirrups in beam to be same size, except use #4 (⊓ 6") stirrups under the bearings; however, do not use the #4 stirrups under the bearings of Prestressed Double-Tee Structures.

For special cases 1 or 2, see page 3.6-1 of this section.

WIDE FLANGES, PLATE GIRDERS & PRESTRESSED GIRDERS **Reinforcement**
END BENT BACKWALL



PART SECTION THRU BACKWALL AND BEAM

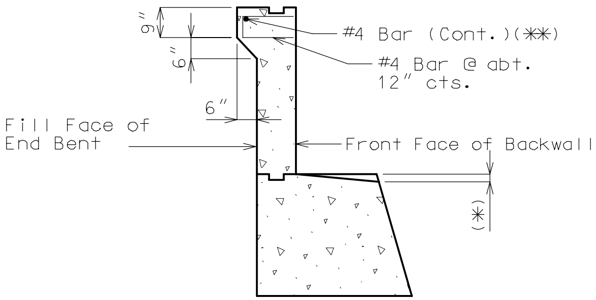
V-BAR SIZE AND SPACING			
h (feet)	t (inch)	Fill Face Reinforcement	Front Face Reinforcement
1-6	12	#5 @ 12"	#5 @ 12"
7	12	#5 @ 12"	#5 @ 12"
8	12	#5 @ 12"	#5 @ 12"
9	12	#6 @ 12"	#5 @ 12"
10	12	#6 @ 10"	#5 @ 12"
11	15	#6 @ 10"	#5 @ 12"
12	15	#6 @ 8"	#5 @ 12"
13	18	#6 @ 8"	#5 @ 12"
14	18	#6 @ 6"	#5 @ 12"

Note:

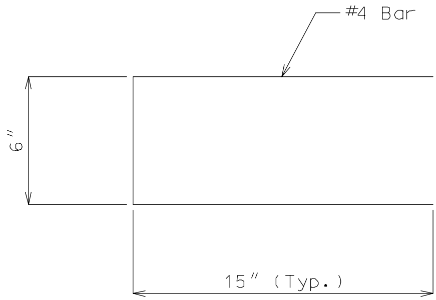
All reinforcement is grade 60.

Design is based on 45 lbs. per cu. ft. equivalent fluid pressure and 90 lbs. per sq. ft. live load surcharge.

Epoxy coat all reinforcing steel in beam and backwall on non-integral end bents with expansion devices.



PART SECTION THRU BACKWALL AND BEAM

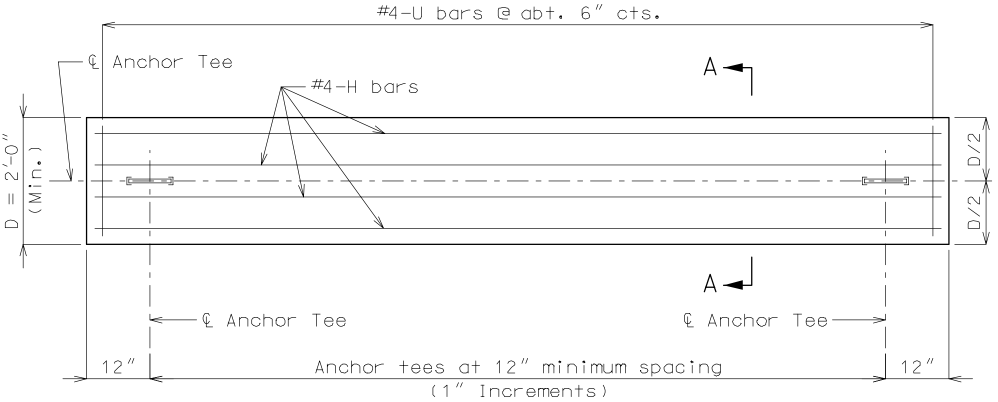


SHAPE 10

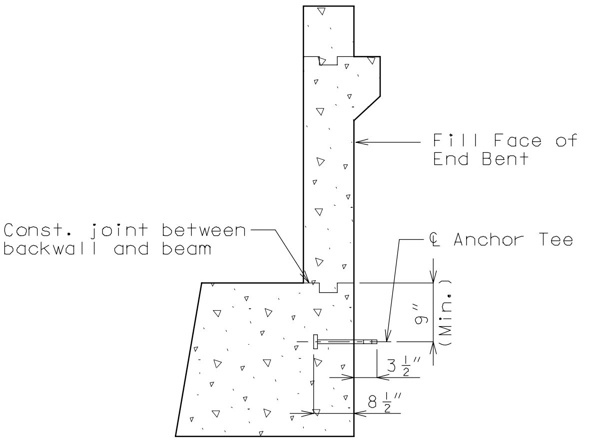
✱ Slope top of beam 1", when using expansion device only.

✱✱ Bar length equals approach haunch length.

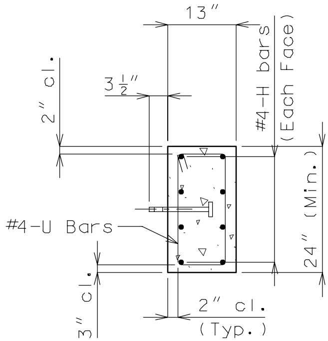
DEADMAN ANCHORS



ELEVATION OF DEADMAN



PART SECTION THRU END BENT



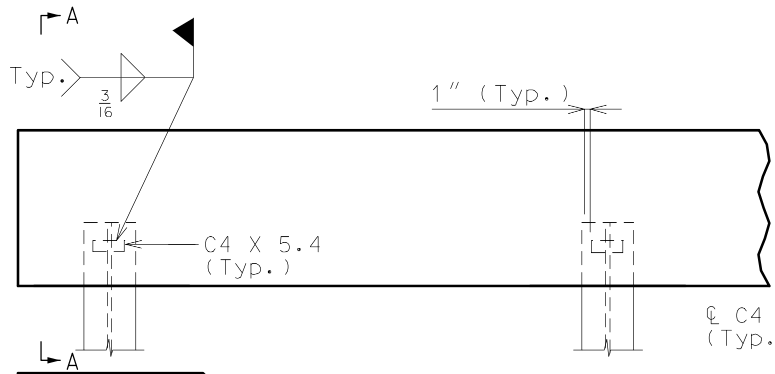
SECTION A-A

Notes:
Anchor tees may be placed in the beam or in the backwall, but must clear the construction joint by a minimum of 9″.

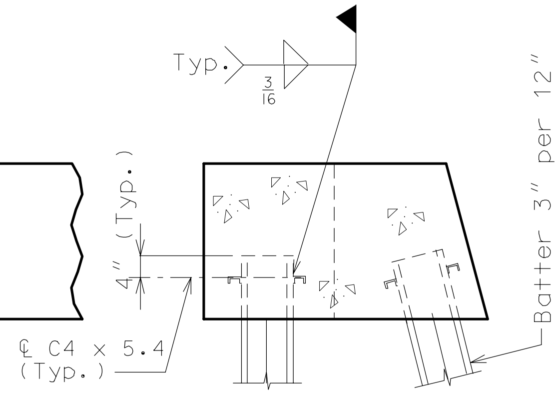
All rods, anchor tees, clevises, turnbuckles and pins to be galvanized and coated with a heavy coating of an approved bituminous paint. Sand below tie rods shall be compacted to a horizontal plane so no bending of the tie rods will occur. Sand above the tie rods shall be hand compacted in such a manner as to avoid damaging the protective coating on the anchor assembly.

ANCHORAGE OF PILES FOR SPC B, C & D.

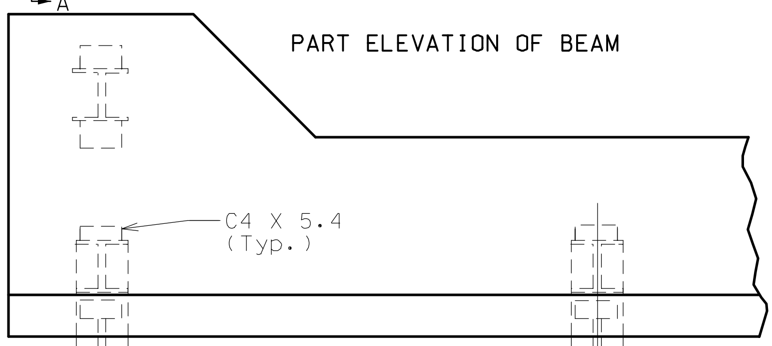
STEEL PILE



PART ELEVATION OF BEAM



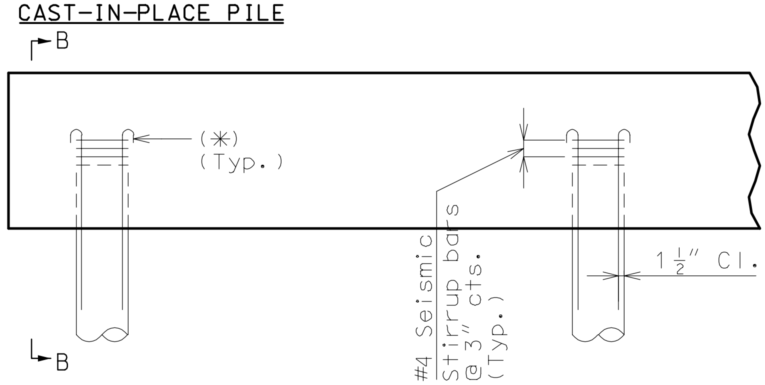
SECTION A-A



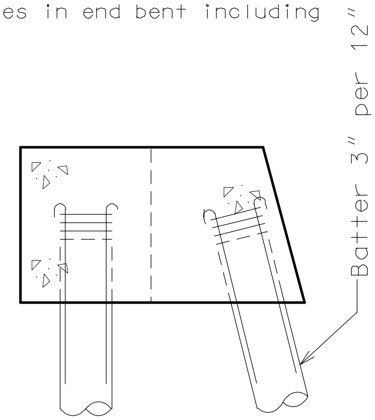
PART PLAN OF BEAM

Note: Channel shear connectors are to be used for all steel piles in end bent including wing pile.

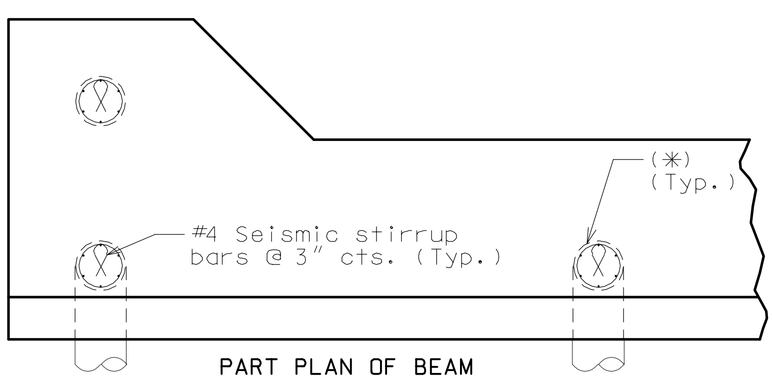
CAST-IN-PLACE PILE



PART ELEVATION OF BEAM



SECTION B-B



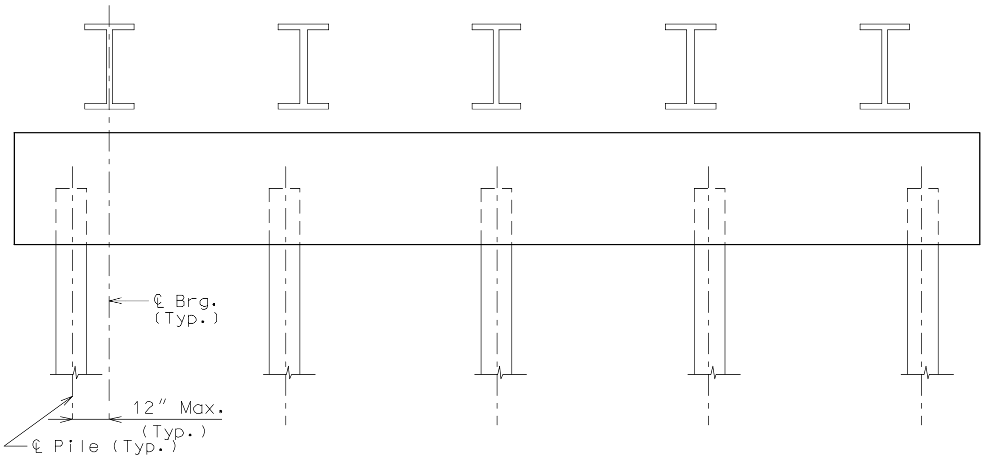
PART PLAN OF BEAM

(✳) See Bridge Manual Section 3.74 (piling) for anchorage reinforcement required.

BEAM REINFORCEMENT SPECIAL CASES

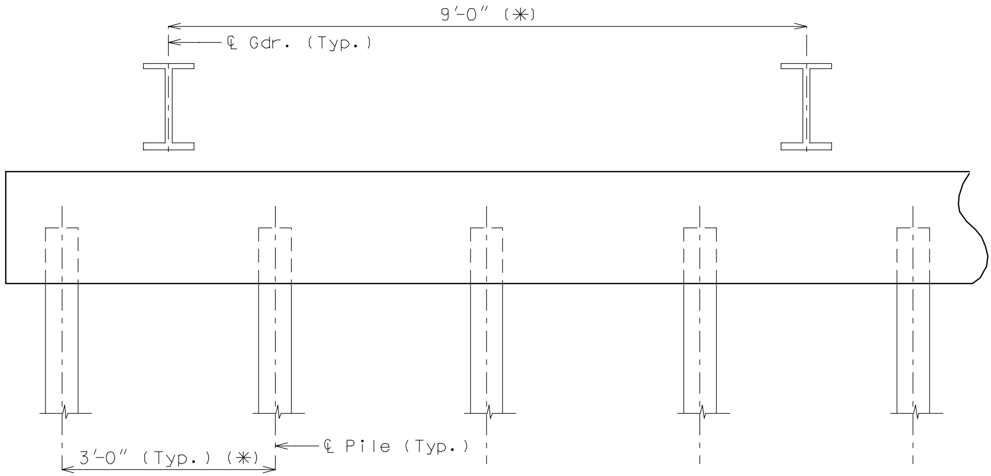
SPECIAL CASE I

If ℄ bearing is 12" or less on either side of ℄ piles, for all piles (as shown below), use 4-#6 top and bottom and #4 at 12" cts. (stirrups), regardless of pile size.



SPECIAL CASE II

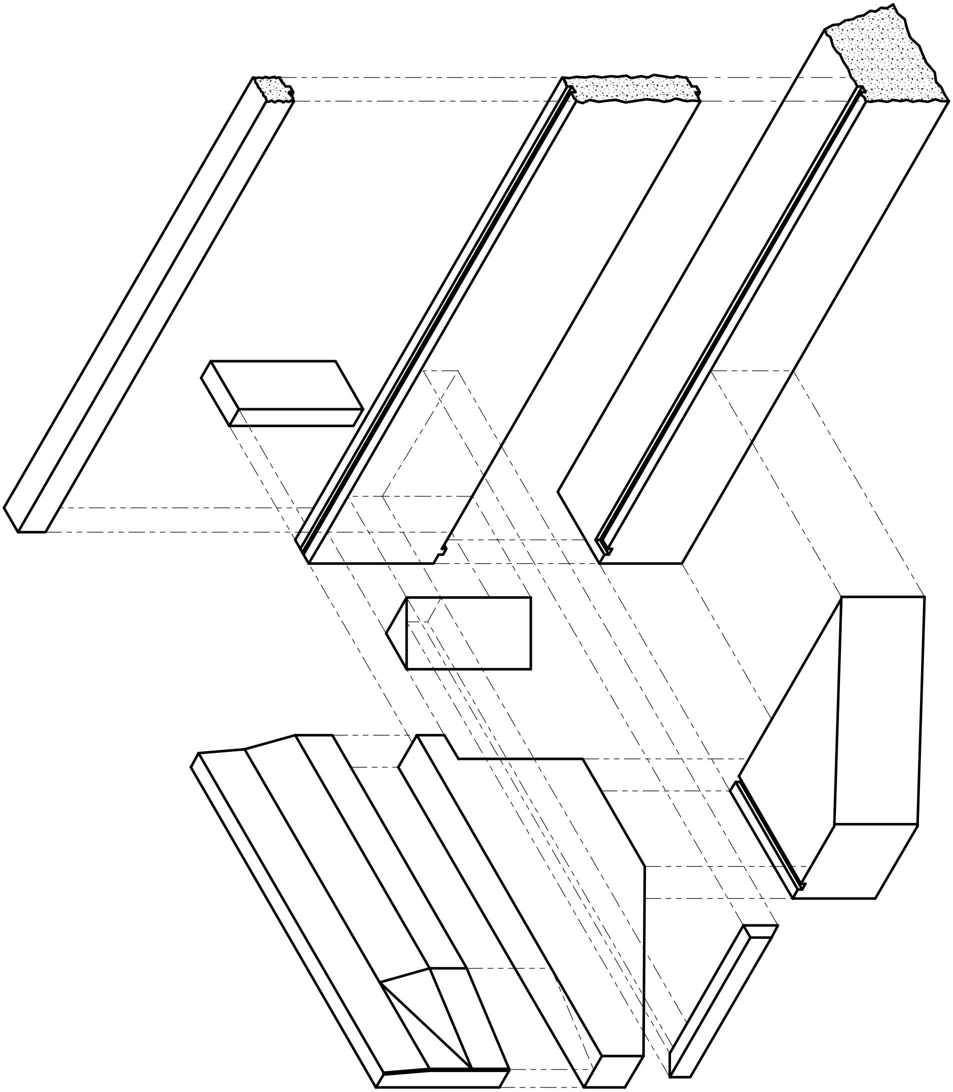
When beam reinforcement is to be designed assuming piles to take equal force, design for negative moment in the beam over the interior piles.



(✳) Dimensions shown are for illustration purposes only.

EXPLODED VIEW OF END BENT Details

SQUARE - STRAIGHT - TURNED BACK WINGS



Note: Exploded view above is above is for information only.

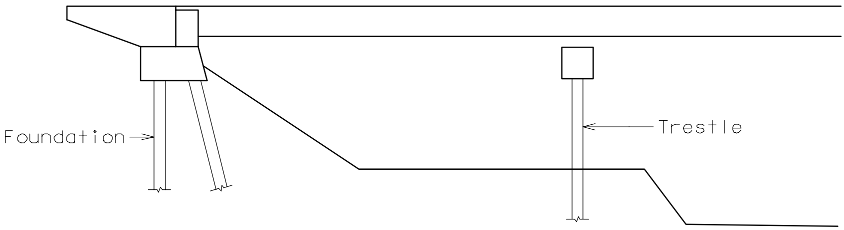
CONCRETE PILES
(CAST-IN-PLACE)

The details of cast-in-place piles will be as indicated on Missouri Standard Plans (English Version) Std. Drawing 702.02., except that the shell and location type must be indicated on the Plans as specified on the Design Layout.

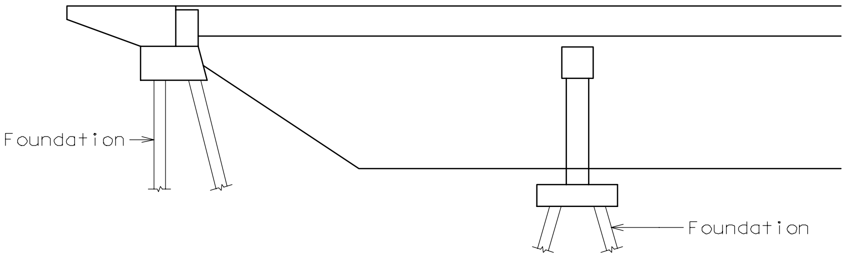
The KIND and TYPE of CIP pile shall be indicated in the "PILE DATA" table on Design Plans.

The TYPE of pile, trestle or foundation, may be selected from the illustrations shown below. When the illustrations indicate that there would be both trestle and foundation piles on the same structure, use all piles as trestle piles throughout the structure, regardless of the type of bent.

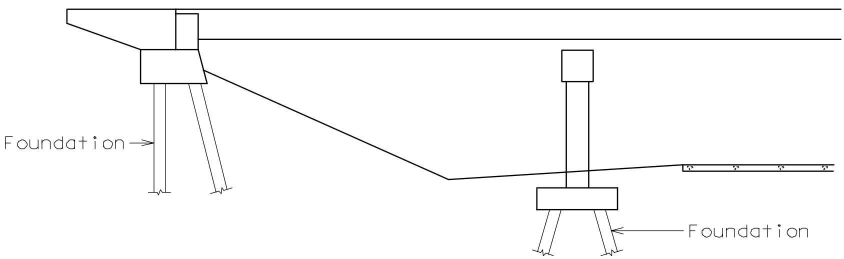
The shell, thick or thin, will not be indicated in the "PILE DATA" table, unless specified on the Design Layout.



STREAM CROSSING



STREAM CROSSING



GRADE SEPARATION

VERTICAL DRAIN AT NON-INTEGRAL END BENTS